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Unleashing the Power of Reinforced Concrete Frames A Comprehensive Study on Seismic Resistance with Masonry Infill Walls in High Risk Zones

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ABSTRACT

Countries like India, the Reinforced concrete frames with masonry infill walls are common in practice, where the region is prone to seismic activity. Generally the masonry infill walls are treated as nonstructural element in structural analysis and only the contribution of its mass is considered and it's structural properties like strength and stiffness is generally not considered. The structures in high seismic areas are greatly vulnerable to severe damages. Apart from the gravity load structure has to withstand to lateral load which may develop high stresses. Now day's reinforced concrete frames are most common in building construction practice around the globe. The vertical gap in reinforced concrete frames i.e. created by the columns and beams are generally filled in by brick or masonry and it is referred as brick infill wall or panels. The main objective of this study is to study seismic resistance of RCC frames for G+8 story building with infill walls by using ETABS software in different seismic zones. The comparison was made between story drift, story shear, bending moment, building torsion between building with and without infill walls.

Key words: infill walls, reinforced concrete frames, RCC frames, ETABS software.

1. Introduction

Earthquake is responsible for ground motion in random fashion, both horizontally and vertically, in all directions radiating from the epicenter. Consequently, structures founded in ground vibrate, inducing inertial forces on them. The structures in high seismic areas are greatly vulnerable to severe damages. Apart from the gravity load structure has to withstand to lateral load which may develop high stresses. Nowadays reinforced concrete frames are most common in building construction practice around the globe. The vertical gap in reinforced concrete frames i.e. created by the columns and beams are generally filled in by brick or masonry and it is referred as brick infill wall or panels. When the construction of frame is done, these walls are built of brunt clay bricks in cement mortar. These walls are typically of 115 TO 200 mm thick. Due to functional requirements the openings are provided in the frames for windows and doors etc.

The major reason behind the use of infill in building is the ease with which it can be constructed that is it generally requires the locally available material. Again, it has the good sound proofing and heat insulating properties those results in the greater comfort for the inhabitants of the buildings.

Reinforced concrete frames with masonry infill walls are a common practice in countries like India, where the region is prone to seismic activity. Generally, the masonry infill walls are treated as nonstructural element in structural analysis and only the contribution of its mass is considered and it's structural properties like strength and stiffness is generally not considered. Although it contributes significantly to the lateral stiffness of the frame structures. There are no such specific references to infill walls in the Indian seismic standard (IS 1893:2002) that is currently used in India. One of the drawbacks of neglecting the infill as a structural member is the irregularities in the building caused by the uncertain position of infill and openings in them.

The traditional modeling of Reinforced concrete frame structures in which the effect of infill is not considered assumes the structures more flexible than they really are. Because of this reason the building codes obtrudes an upper limit to the natural period of a structure. The contradiction may occur in the analysis and proportioning of structural member in traditional modeling because it does not take strength and stiffness characteristic into account. Actually, there is increase in the overall stiffness of the structure by the effect of infill walls which finally leads to the shorter time periods.

To understand the effect of infill masonry on the lateral strength and stiffness of structures various experiments have been conducted since early 50's. Actually, the lateral load carrying mechanism is modified from the primary frame action to primary truss action by the effect of infill, which causes the increase in axial force and decrease in bending moment and shear force of the frame members. There is generally increase in damping of structures due to the generation of cracks with growing lateral drift. The infill walls may adversely affect the structure during the seismic excitation if it is not placed properly. The non-appearance of infill wall in a certain storey may lead to the soft storey effect which is one of the major ill effects of the infill walls.

2. Objectives of the study

The following are the main objectives of the project

1. To study the seismic behavior of multi storey building by using IS 1893:2002
2. To compare the multi storey buildings with and without infill walls for G+8 story building.
3. To compare the results of Story Drift, Shear force, bending moment, Building torsion of buildings with and without infill walls.
4. To study the buildings in ETABS V9.7.4 in Response spectrum analysis.

3. Literature review

The study by Jonathan et al. (2024) investigates the impact of infill on drift demands and drift capacities in reinforced concrete frames. The results show that infill reduces drift demand more than it reduces drift capacity. Field data from low-rise school buildings supports this, with surveys showing that frames with more full-height infill walls have less earthquake damage. The study suggests that using infill walls in buildings can reduce the likelihood of severe structural damage by 300%, making it an inexpensive and effective retrofit technique for strengthening buildings vulnerable to earthquake damage. Panel Mehdi Hemmat et.al (2024) Confined Semi-Interlocking Masonry (CSIM) system, combining Semi-Interlocking Masonry (SIM) panels with Confined masonry (CM), aims to improve seismic performance in confined masonry buildings. The system combines walls to resist gravity and lateral loads, acting as energy dissipation devices. The study assessed the structural capacity and seismic performance of CSIM through an experimental in-plane cyclic test using the Digital Image Correlation method.

Özge Onat, Pınar Usta Evci (2024) Infl walls, often overlooked due to their complexity, significantly impact structures during earthquakes. A study in Turkey found that infl walls positively affect building properties like period, shear force, and drift ratio, but autoclaved aerated concrete blocks showed lower stifness. Ping Tan [a b], Liangkun Liu et.al (2023) prepossessed a novel control system called a Linked Building with a Vibration-Suppression Layer (LBVSL) to reduce seismic responses in LBs with strong connections. The LBVSL significantly reduces vibration energy and responses compared to plain LBs, with optimal parameters achieving 69% reduction. Ali Zine et.al (2021) investigated the seismic performance of reinforced concrete frame buildings with masonry infill panels in seismic zones. It uses non-linear inelastic behavior and micro and macro models. The results show that the presence of non-structural masonry infills significantly improves the seismic response of these structures, affecting their initial rigidity and strength.

4. Methodology

Software and Analysis Approach

ETABS software (v 9.7.4) was employed to perform response spectrum analysis. The models were developed for two scenarios: (1) RCC frame without infill walls and (2) RCC frame with masonry infill walls. Parameters adhered to IS 1893:2002 seismic code standards.

Model Specifications

Building Type: Residential (G+8 stories)

Dimensions: Beam (230mm x 460mm), Column (230mm x 690mm), Slab Thickness (150mm)

Material Properties: Concrete Grade M40, Steel HYSD Fe550

Loads: Dead Load (2 kN/m), Live Load (5 kN/m), Earthquake Load (Zone II)

Analysis Parameters

Seismic zones, damping ratios, and structural class specifications were incorporated as per IS 456:2000 and IS 800:2007. The equivalent diagonal strut method was used to simulate masonry infill walls.

Statement of the project

In the present study, analysis of G+ 8 stories building in Zone II seismic zones is carried out in ETABS.

Basic parameters considered for the analysis are

1. Utility of Buildings : Residential Building
2. No of Storey : 9 Stories (G+8 Building)
3. Grade of concrete : M40
4. Grade of Reinforcing steel : HYSD Fe550
5. Type of construction : RCC framed structure
6. Dimensions of beam : 230mmX460mm
7. Dimensions of column : 230mmX690mm
8. Thickness of slab : 150mm
9. Thickness of Infill wall : 230mm
10. Height of bottom story : 4m
11. Height of Remaining story : 3m
12. Building height : 34m
13. Live load : 5 KN/m^2
14. Dead load : 2 KN/m^2
15. Density of concrete : 25 KN/m^3
16. Loads considered in Buildings : Dead load, Live load, Floor load ,Earthquake ,Wind load
17. Seismic Zone : Zone II
18. Site type : II
19. Importance factor : 1.5
20. Response reduction factor : 5
21. Damping Ratio : 5%
22. Structure class : B
23. Basic wind speed : 44m/s
24. Method of Analysis : RESPONSE SPECTRUM ANALYSIS
25. Wind design code : IS 875: 1987 (Part 3)
26. RCC design code : IS 456:2000
27. Steel design code : IS 800: 2007
28. Earth quake design code : IS 1893 : 2002 (Part 1).

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5. Result:

Drift is the side movement of a building. Story drift is how a multistory building moves compared to the floor below. Inter storey drift measures the difference between roof and floor movements in an earthquake, related to story height. Greater drift increases damage risk, with over 0. 06 indicating severe damage and over 0. 025 posing serious safety risks. Values over 0. 10 suggest possible building collapse.

Table 5. 1Drift in X direction

Story Number	Load	Drift X in m without infill wall	Drift X in m with infill wall
9	RSA	0.00014	0.000004
8	RSA	0.00024	0.000005
7	RSA	0.00034	0.000005
6	RSA	0.00044	0.000006
5	RSA	0.00052	0.000006
4	RSA	0.00059	0.000006
3	RSA	0.00066	0.000006
2	RSA	0.00071	0.000005
1	RSA	0.00063	0.000004

Graph 5. 1 Comparison of Drift in X direction

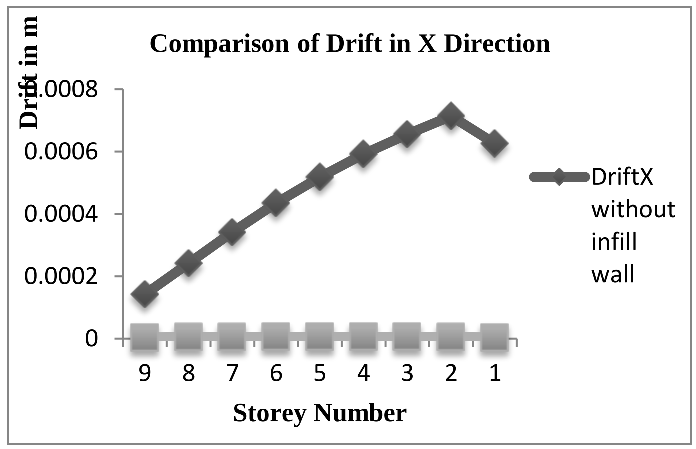
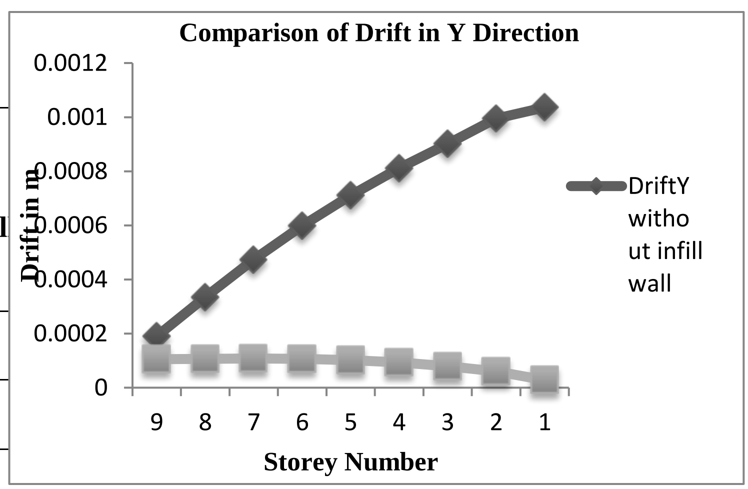


Table 5. 2 Drift in Y direction

Graph 5. 2 Comparison of Drift in Y direction

Story Number	Load	Drift Y in m without infill wall	Drift Y in m with infill wal
9	RSA	0.00019	0.000105
8	RSA	0.00034	0.000107



7	RSA	0.00047	0.000108
6	RSA	0.0006	0.000107
5	RSA	0.00071	0.000102
4	RSA	0.00081	0.000093
3	RSA	0.0009	0.000079
2	RSA	0.001	0.00006
1	RSA	0.00104	0.000028

Story shears and over turning moments

Story shears and overturning moments are reported in the global coordinate system as P, VX, VY, T, MX and MY. The forces are reported at the top of the story, just below the story level itself, and at the bottom of the story, just above the story level below.

The sign convention for story level forces is exactly the same as that for frame elements with the bottom of the story corresponding to the i-end of the frame element and the top of the story corresponds to the j-end of the frame element. The story shears and overturning moments are always reported at the following locations; Global X=0, Global Y=0 and Global Z is as described in the above paragraph.

The frame element internal forces are:

- P, the axial force
- V2, the shear force in the 1-2 plane
- V3, the shear force in the 1-3 plane
- T, the axial torque (about the 1-axis)
- M2, the bending moment in the 1-3 plane (about the 2-axis)
- M3, the bending moment in the 1-2 plane (about the 3-axis)

These internal forces and moments are present at every cross section along the length of the frame element.

5.3 Building torque (T)

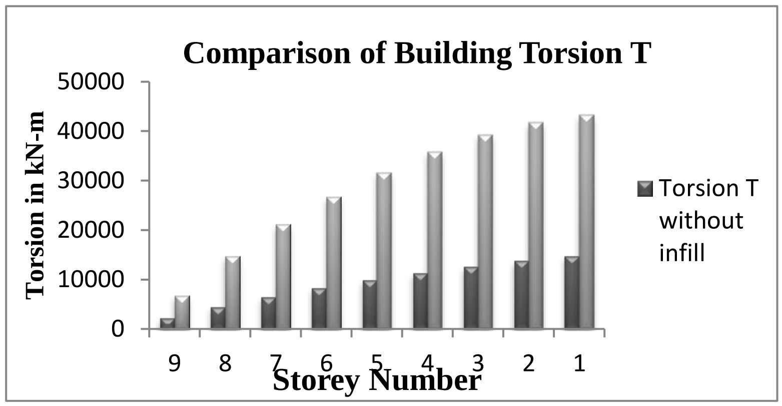
Torque is a twisting or turning force that tends to cause rotation around an axis, which might be a center of mass or a fixed point.

Torque can also be thought of as the ability of something that is rotating, such as a gear or a shaft, to overcome turning resistance.

Table 5. 3 Torsion values

Story Number	Load	Torsion T in kN-m without infill	Torsion T in kN-m with infill
9	RSA	2187.14	6749.22
8	RSA	4439.2	14689.7
7	RSA	6440.21	21177.2
6	RSA	8245.47	26693.8
5	RSA	9870.69	31540.6
4	RSA	11313.7	35768
3	RSA	12596.4	39239.5
2	RSA	13749.4	41744.6
1	RSA	14681.7	43272.4

Graph 5. 3 Comparison of Building torque



5.4 Story shear

The shear force at the cross section of the beam may be defined as the un balanced vertical force to the right or left of the section.

Table 5. 4 Storey shear X direction

Graph 5. 4 Comparison of shear in X direction

Story Number	Load	Shear VX in kN without infill	Shear VX in kN with infill
9	RSA	73.83	128.97
8	RSA	149.9	299.46
7	RSA	216.59	448.67
6	RSA	274.93	576.33
5	RSA	325.71	682.95
4	RSA	368.57	768.82
3	RSA	403.19	834.23
2	RSA	428.81	879.47
1	RSA	443.71	907.15

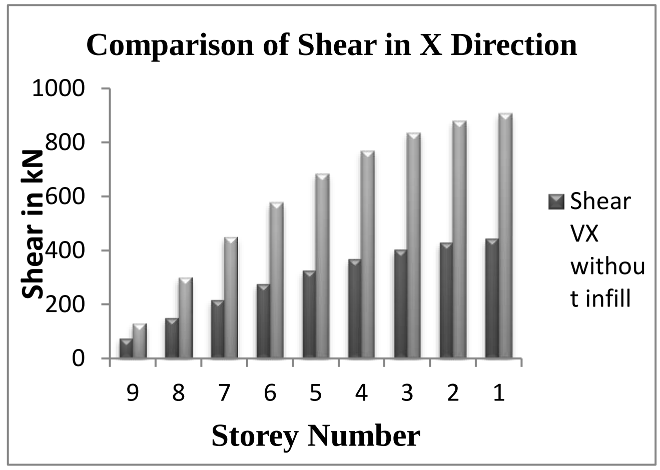
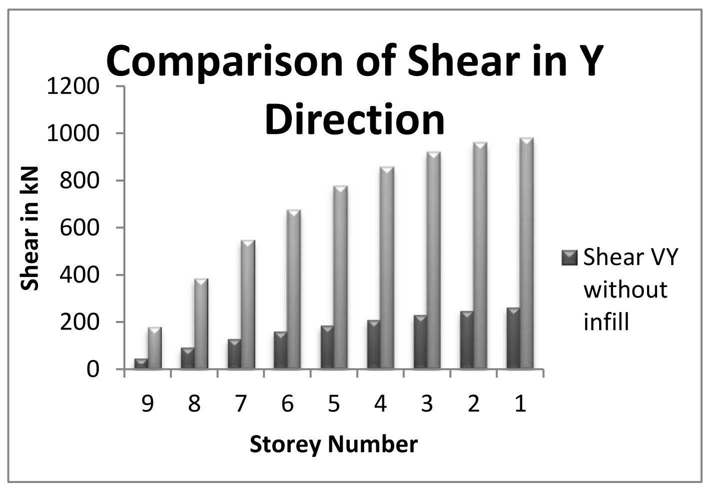


Table Storey shear Y direction Graph 5. 5 Comparison of shear in Y direction

Story Number	Load	Shear VY in kN without infill	Shear VY in kN with infill
9	RSA	45.26	179.34
8	RSA	90.48	385.67
7	RSA	128.06	546.82
6	RSA	159.05	673.98
5	RSA	185.2	776.06
4	RSA	208.13	857.85
3	RSA	228.89	919.86
2	RSA	247.36	960.31
1	RSA	262.52	980.69



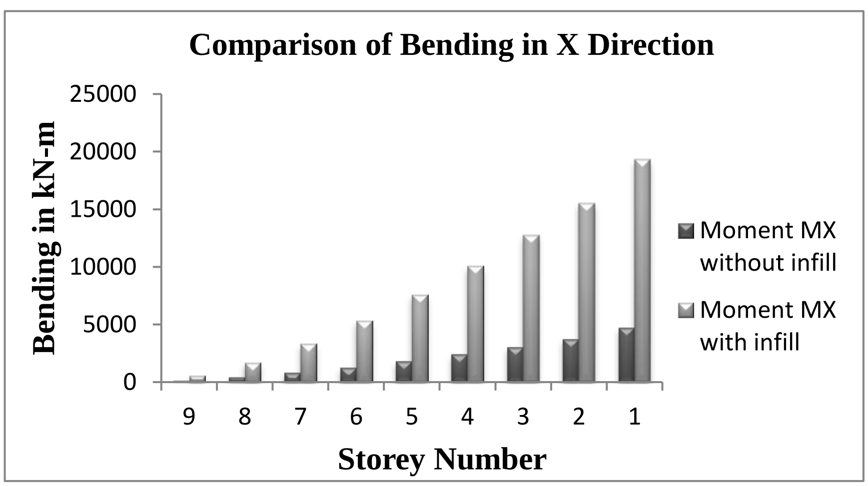
5.5 Bending moment

The Bending moment at the cross section of the beam may be defined as the un balanced vertical moment to the right or left of the section.

X Direction

Table 5. 5 Bending moment in X direction

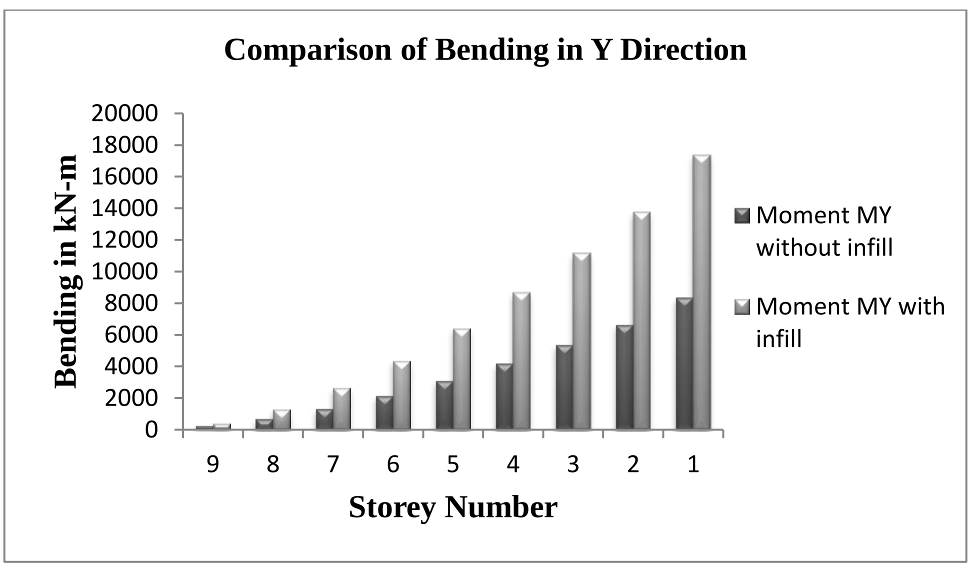
Story Number	Load	Moment MX in kN-m without infill	Moment MX in kN-m with infill
9	RSA	135.789	538.012
8	RSA	406.59	1691.443
7	RSA	787.645	3318.96
6	RSA	1256.963	5311.165
5	RSA	1797.505	7586.391
4	RSA	2397.52	10082.26
3	RSA	3049.432	12745.62
2	RSA	3747.666	15525.22
1	RSA	4735.926	19331



Graph 5. 6 Comparison of Bending moment in X direction

Table 5. 6 Bending moment in Y direction

Story Number	Load	Moment MY in kN-m without infill	Moment MY in kN-m with infill
9	RSA	221.489	386.912
8	RSA	670.663	1285
7	RSA	1317.41	2629.27
6	RSA	2133.84	4353.01
5	RSA	3095.95	6391.29
4	RSA	4180.45	8681.11
3	RSA	5363.01	11161.2
2	RSA	6618.04	13772.4
1	RSA	8353.75	17364.7



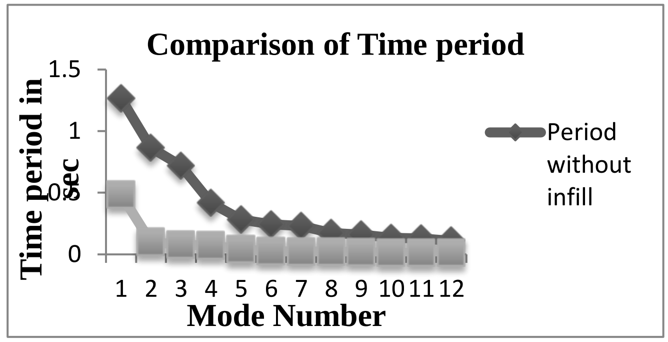
Graph 5. 7 Comparison of Bending moment in Y direction

5.6 Time Period

Table 5. 7 Comparison of time period

Mode	Period in seconds without infill	Period in seconds with infill
1	1.266077	0.486312
2	0.86418	0.100106
3	0.719997	0.077531
4	0.418136	0.071806
5	0.281754	0.04207
6	0.244437	0.024878
7	0.231612	0.023612
8	0.172285	0.02227
9	0.161759	0.017275
10	0.133182	0.013257
11	0.129545	0.01262
12	0.109895	0.01205

Graph 5. 8 Comparison of time period Values



5.7 Storey Shear Curves

Without infill walls

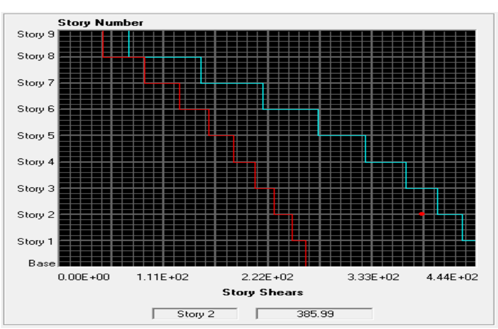


Fig 5. 1 Storey shear without infill walls

With infill walls

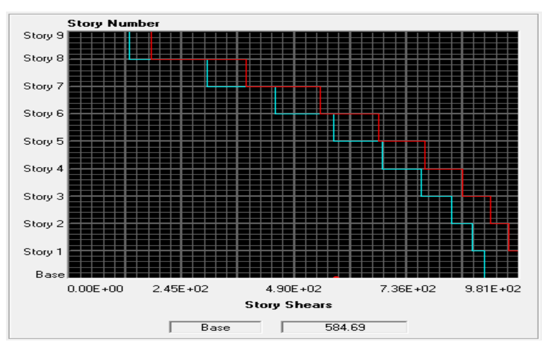


Fig 5. 2 Storey shear with infill walls

6. Conclusion:

In this study, response spectrum analysis was conducted for a G+10 RC building with masonry infill walls. Key conclusions include that infill walls significantly affect structural behavior and are crucial for seismic analysis. Masonry infill walls are common, cost-effective, and durable in many countries. They support the building's perimeter while separating inner and outer spaces. The analysis shows higher drift values in buildings without infill walls and higher story shear, bending, and torsion values with infill walls, indicating reduced deflection when using masonry infill.

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