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ANALYSIS AND DESIGN OF A TYPICAL DUPLEX BUILDING UNDER DIFFERENT SEISMIC ZONES USING STAAD PRO AND COST COMPARISON

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ABSTRACT

The principal objective of this project is to analysis and design a duplex building (G+1) using STAAD Pro with and without seismic provisions and to compare the cost. The design involves load calculations manually and analyzing the whole structure by STAAD Pro. The design method used in STAAD-Pro analysis is Limit State Design conforming to Indian Standard Codes of Practice. STAAD.Pro features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite elements and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification, STAAD.Pro is the professional's choice. In this project analysis and design of a real-life G+1 duplex building is carried out for all possible load combinations of dead, live, wind and seismic loads.

1. INTODUCTION

Our project involves analysis and design of duplex building [G+1] using a very popular designing software STAAD Pro. We have chosen STAAD Pro because of its following advantages:

- Easy to use interface,
- Conformation with the Indian Standard Codes,
- Versatile nature of solving any type of problem,
- Accuracy of the solution.

STAAD.Pro features a state-of-the-art user interface, visualization tools, powerful analysis and design engines with advanced finite elements and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification, STAAD.Pro is the professional's choice for steel, concrete, timber, aluminum and cold-formed steel design of low and high-rise buildings, culverts, petrochemical plants, tunnels, bridges, piles and much more.

STAAD.Pro consists of the following:

The STAAD.Pro Graphical User Interface: It is used to generate the model, which can then be analyzed using the STAAD engine. After analysis and design is completed, the GUI can also be used to view the results graphically.

The STAAD analysis and design engine: It is a general-purpose calculation engine for structural analysis and integrated Steel, Concrete, Timber, and Aluminum design.

To start with we have solved some sample problems using STAAD Pro and checked the accuracy of the results with manual calculations. The results were too satisfactory and were accurate. In the initial phase of our project, we have done calculations regarding loadings on buildings and considered seismic and wind loads.

2. LITERATURE REVIEW

- Jitendra Ahirwar and Anil Kumar Saxenar (2022), Structures on the earth are generally subjected to two types of load i.e. static and dynamic. Static loads are constant with time while dynamic loads are time varying. In general majority of the civil structures are designed with the assumption that all applied loads are static. The effect of dynamic load is not being considered because the structure is rarely subjected to dynamic loads, more its consideration in the analysis makes the solution more complicated and time consuming.
- Mr. Rahul Kundlik Pacharne, Prof. Amol Suryakant Pote & Prof. Girish Vinayak Joshi (2023), The objective in this Research aims to make use of STAAD Pro to analysis and design a high-rise structure using the G+25 IS codes. Automated calculation of loads and STAAD Pro structural analysis are applied in the design processes. It viewed a 3-D RCC frame in a dimension of 6 bay within x-axis and 5 bay within z-axis. The G+25 floor represented the axis of y.

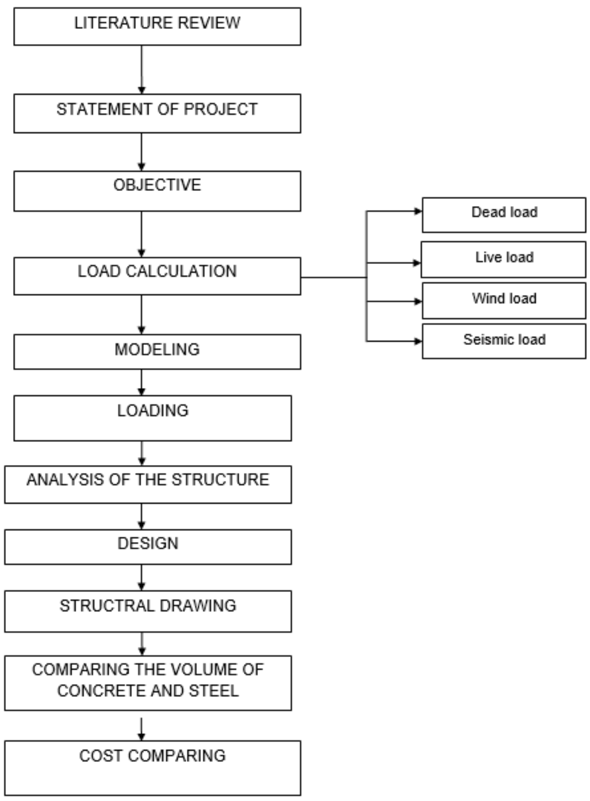
- Ankit Bhaskar, Ajay Kumar, Mamta Gupta, Anurag Upadhyay & Surya Prakash Sharma (2020), Planning a structure so that lessening harm during a quake makes the structure very uneconomical, as the seismic tremor may or probably won't happen in its life time and is an uncommon marvel. In this paper a G+6 existing RCC encircled structure has been broke down and planned utilizing STAAD.Pro V8i. The structure is planned according to IS 1893(Part 1):2002 for tremor powers in various seismic zones.
- Kavita Verma & Ahsan Rabbani (2020), There is a large portion of India which is affected by damages caused by earthquake. So it is necessary to consider seismic load in design of structure. From the recent earthquakes it is concluded that not only non-engineered but also the engineered structure is affected by earthquake.

3. OBJECTIVES

The following are the objectives of this project.

- Modeling of a framed structure from the given plan
- Analyzing and designing of beams and columns through STAAD Pro and foundation through STAAD Foundation for gravity load, wind load and seismic load.
- Analysis is to be carried out for cities of different seismic zones. These cities are Bhopal (seismic zone 2), Mumbai (seismic zone 3), Delhi (seismic zone 4) and Guwahati (seismic zone 5).
- Design of RCC slabs is to be carried out manually with an excel sheet to develop for working out moment coefficients for different edge conditions as per IS code.
- Comparing the quantities of concrete and steel worked out in each analysis/ design for different cities.
- To make a comparison of the cost of building in each analysis/ design for different city for different load combinations.

4. METHOLODOGY



5. RESULT AND DISCUSSION

The analysis and design were done according to standard specifications to the extent possible. For analyzing the beams and the columns, we had assumed the width of the beam on the architectural considerations and some theoretical knowledge. The depth of the beams was decided according to Clause 23.2.1 of IS 456: 2000.Leaving some sections, all the sections were passed, and the failed section had been reconsidered. After the analysis and designing various results like maximum bending moment, maximum shear force, maximum axial force, maximum joint displacement, and maximum section displacement are evaluated, and effective and critical floor is determined among the structure considering combined factored dead and live load. After analysis STAAD shows the quantity of concrete

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and steel for the beams and columns. For slabs staircases and foundation, we have calculated the volume of concrete and reinforcement is calculated on thumb rule i.e. one cum of slab and isolated footing contains 70kg of reinforcement whereas in staircases and raft one cum contains 100 kg of reinforcement.

For comparing the costs, we have taken the rates from the D.S.R published by the C.P.W.D. Delhi. The following are the rates.

- M-20 grade concrete – Rs 7390.80 per cum
- M-25 grade concrete (up to plinth level) – Rs 6446.45 per cum
- M-25 grade concrete (above plinth level) – Rs 7250.05 per cum
- Fe-415 steel – Rs 56.60 per kg

Finally, we would consider that R.C.C works is 50% of the total cost of building

Table 1: Quantity of concrete and reinforcement in different loading conditions

CITY	COMPONENT	GRAVITY LOAD		WIND LOAD		EARTHQUAKE LOAD	
		CONC (m^3)	STEEL (kg)	CONC (m^3)	STEEL (kg)	CONC (m^3)	STEEL (kg)
BHOPAL (SEISMIC ZONE II)	SLAB + STAIRCASE	47.75	3650	47.75	3650	47.75	3650
	BEAMS + COLUMNS	97.3	9806.3	97.3	9855.3	97.3	10570.5
	FOUNDATION	74.387	5207.06	74.5783	5247.97	78.7085	5469.595
	TOTAL	**219.44**	**18663.4**	**219.6283**	**18753.27**	**223.7585**	**19690.1**
MUMBAI (SEISMIC ZONE III)	SLAB + STAIRCASE	47.75	3650	47.75	3650	47.75	3650
	BEAMS + COLUMNS	97.3	9806.3	97.3	9884.3	110.1	10643.7
	FOUNDATION	74.387	5207.06	74.72525	5295.768	84.338	5963.66
	TOTAL	**219.44**	**18663.4**	**219.7753**	**18830.07**	**242.188**	**20257.36**
DELHI (SEISMIC ZONE IV)	SLAB + STAIRCASE	47.75	3650	47.75	3650	47.75	3650
	BEAMS + COLUMNS	97.3	9806.3	97.3	9929.5	119.8	12443.9
	FOUNDATION	74.387	5207.06	74.9605	5331.235	93.58575	6641.003
	TOTAL	**219.44**	**18663.4**	**220.0105**	**18910.74**	**261.1358**	**22734.9**
GUWAHATI (SEISMIC ZONE V)	SLAB + STAIRCASE	47.75	3650	47.75	3650	47.75	3650
	BEAMS + COLUMNS	97.3	9806.3	97.3	9953.5	122.7	15677.4
	FOUNDATION	74.387	5207.06	75.407	5384.49	116.231	8386.17
	TOTAL	**219.44**	**18663.4**	**220.457**	**18987.99**	**286.681**	**27713.57**

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Table 2: Cost of concrete and reinforcement in different loading conditions

CITY	CONDITION	GRAVITY LOAD CONC (RS)	GRAVITY LOAD STEEL (RS)	WIND LOAD CONC (RS)	WIND LOAD STEEL (RS)	EARTHQUAKE LOAD CONC (RS)	EARTHQUAKE LOAD STEEL (RS)
BHOPAL	SLAB + STAIRCASE	352910	206590	352910	206590	352910	206590
	BEAMS + COLUMNS	719124	555036	719124	557809	719124	598290
	FOUNDATION	494406	294719	495680	297035	523132	309579
	TOTAL	**1566441**	**1056345**	**1567716**	**1061435**	**1595167**	**1114459**
MUMBAI	SLAB + STAIRCASE	352910	206590	352910	206590	352910.7	206590
	BEAMS + COLUMNS	719124	555036	719124	559451	813727	602433
	FOUNDATION	494406	294719	496657	299740	560548	337543
	TOTAL	**1566441**	**1056345**	**1568693**	**1065781**	**1727186**	**1146566**
DELHI	SLAB + STAIRCASE	352910	206590	352910	206590	352910	206590
	BEAMS + COLUMNS	719124	555036	719124	562009	885417	704324
	FOUNDATION	494406	294719	498221	301747	622013	375880
	TOTAL	**1566441**	**1056345**	**1570256**	**1070347**	**1860341**	**1286795**
GUWAHATI	SLAB + STAIRCASE	352910	206590	352910	206590	352910	206590
	BEAMS + COLUMNS	719124	555036	719124	563368	906851	887340
	FOUNDATION	494406	294719	501188	304762	772523	474657
	TOTAL	**1566441**	**1056345**	**1573224**	**1074720**	**2032285**	**1568588**

Comparison of different results

Table 3: Comparison of volume of concrete and percentage variation with respect to gravity load

Type of loading	volume of concrete (m^3)	% variation
Gravity loads [DL+LL]	219.4365	-----------
Seismic Zone II [DL+LL+EL]	223.7850	1.94
Seismic Zone III [DL+LL+EL]	242.1880	7.59
Seismic Zone IV [DL+LL+EL]	261.1358	7.25
Seismic Zone V [DL+LL+EL]	286.6810	8.91

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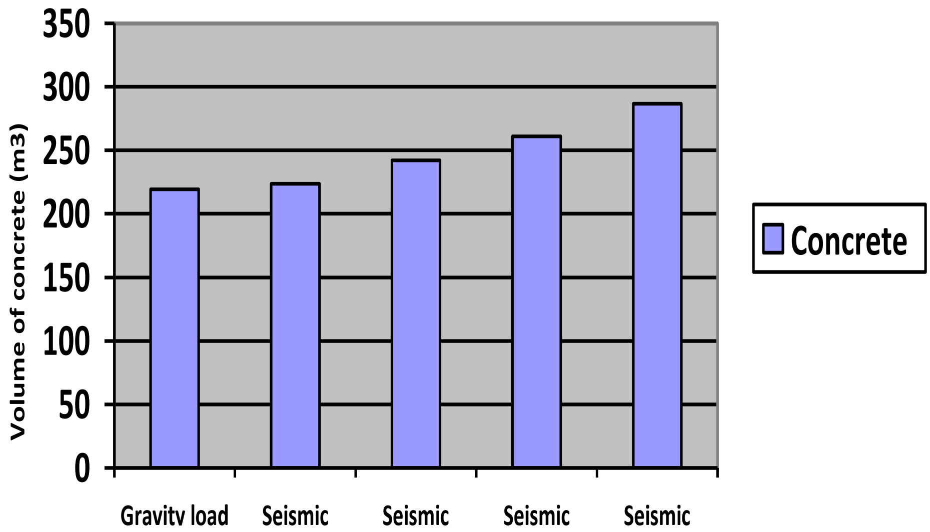
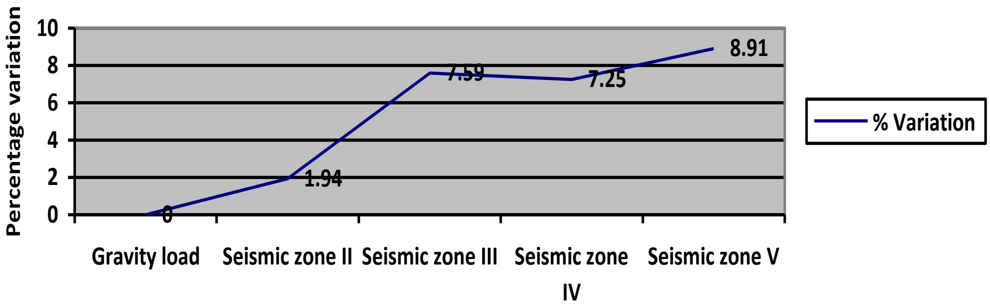


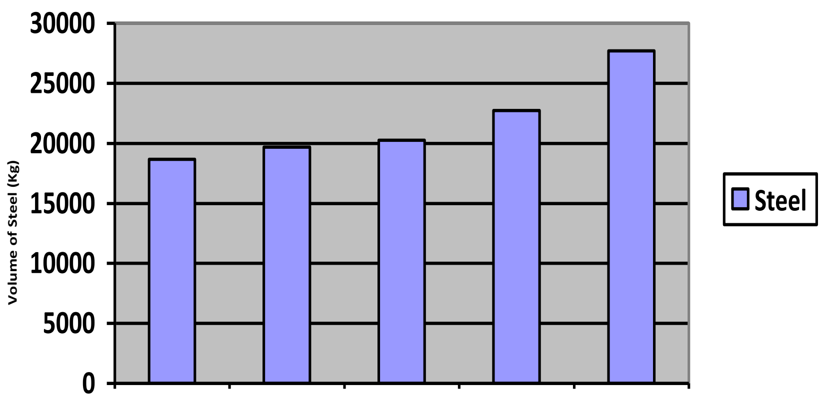
Graph showing variation of volume of concrete.



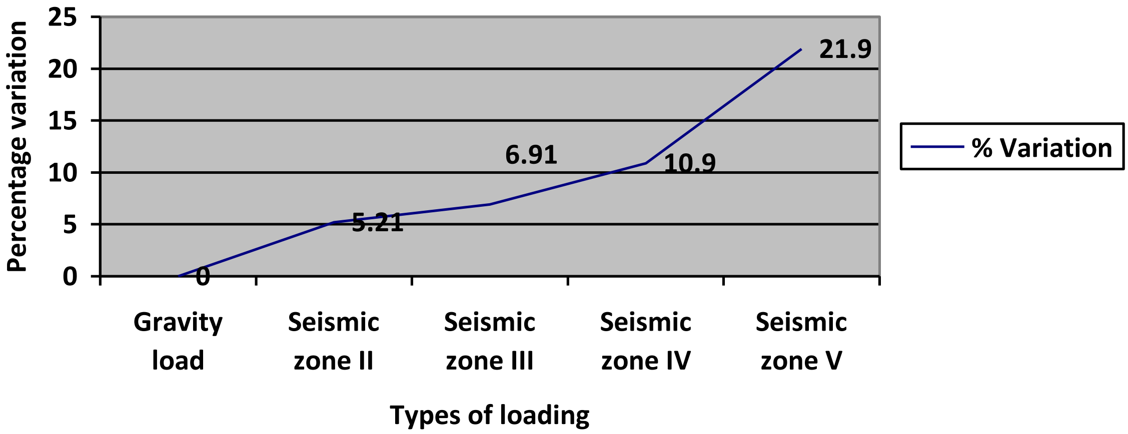
Graph showing percentage variation of volume of concrete.

Table 4: Comparison of volume of steel and percentage variation with respect to gravity load

Type of loading	weight of steel(Kg)	% variation
Gravity loads [DL+LL]	18663.36	--------
Seismic Zone II [DL+LL+EL]	19690.10	5.21
Seismic Zone III [DL+LL+EL]	20257.36	2.80
Seismic Zone IV [DL+LL+EL]	22734.90	10.90
Seismic Zone V [DL+LL+EL]	27713.57	21.92



Graph showing variation of weight of steel.



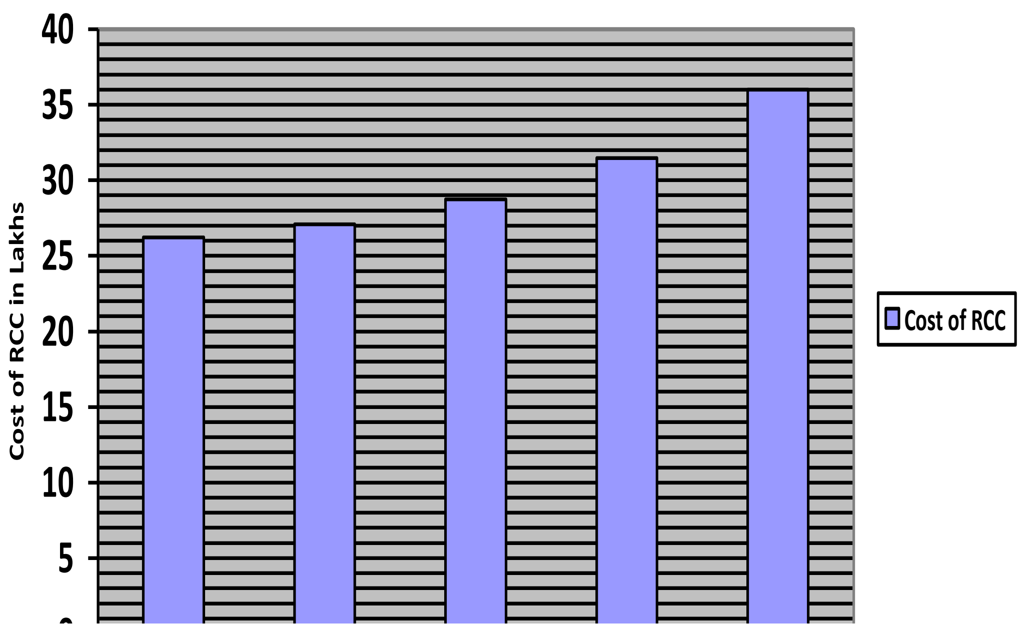
Graph showing percentage variation of weight of steel.

Table 5: Comparison of cost of R.C.C

Type of loading	Cost of R.C.C. (in Rs.)
Gravity loads [DL+LL]	2622787
Seismic Zone II [DL+LL+EL]	2709626
Seismic Zone III [DL+LL+EL]	2873752
Seismic Zone IV [DL+LL+EL]	3147136
Seismic Zone V [DL+LL+EL]	3600873

Table 6: Comparison of percentage variation of cost of R.C.C

Type of loading	% variation
GL vs Seismic Zone II	3.20
GL vs Seismic Zone III	8.73
GL vs Seismic Zone IV	16.66
GL vs Seismic Zone V	27.16



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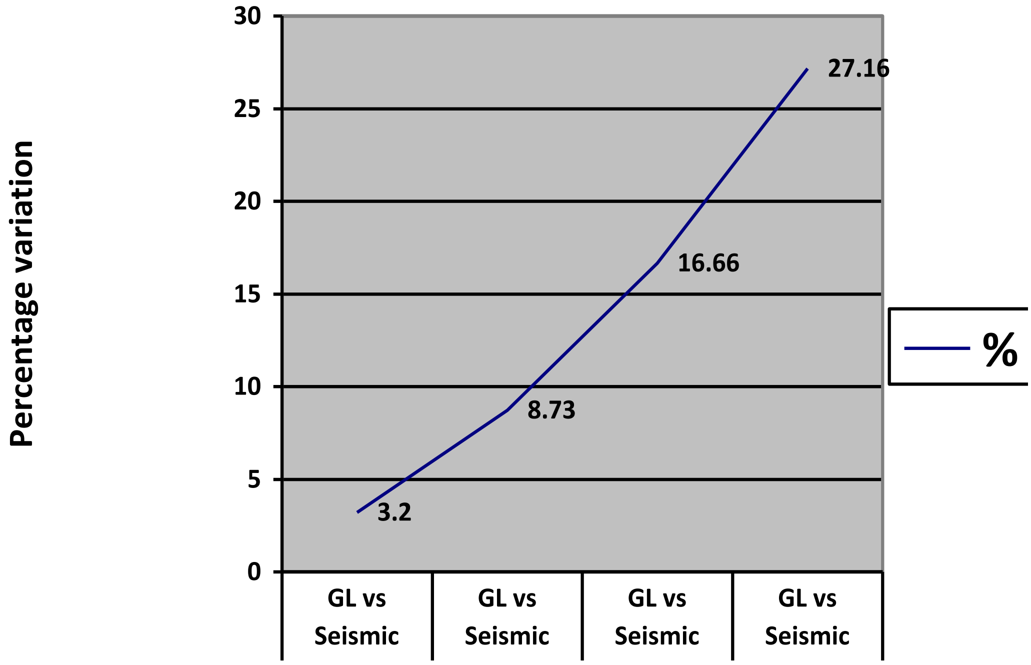
Graph showing comparison of cost of R.C.C.



Graphshowing Comparison of percentage variation of cost of earthquake resistant building vs. non- earthquake building

6. CONCLUSIONS

Following important conclusions are drawn from this project: -

- Earthquake resistant analysis design of real-life multistory buildings can be carried
- out using powerful tools like STAAD Pro. However, extreme care is needed to understand and feed data in an accurate manner, else there may be blunders. The various difficulties encountered in the design process and the various constraints faced by the structural engineer in designing up to the architectural drawing also need to be properly understood and sorted to arrive at proper design.
- STADD is a very powerful tool; still some designs like design of slabs can be more conveniently carried out manually. The excel sheet developed as a part of this project successfully carried out slab design as per the provisions of IS 456: 2000.
- It is found that the volume of concrete in footing near the shear walls increases in seismic zones IV and V due to increase of support reactions with the effect of lateral forces.
- It is found that the percentage of bottom middle reinforcement is almost same for both earthquake resistant and non-earthquake resistant designs in the external and internal beams.
- The percentage variation of total concrete quantity for the whole structure (including foundation), between gravity load design and seismic load design for seismic zones II, III, IV and V is found to vary as 1.94 %, 7.59 %, 7.25% and 8.91 % respectively.
- Percentage variation of total reinforcement quantity for the whole (including foundation between gravity load design and seismic load design for seismic zones II, III, IV and V is found to vary as 5.21 %. 2.80 %, 10.90 % and 21.92 % respectively.
- It is found that the percentage variation of cost for the whole structure (including foundation), between gravity load design and seismic load design for seismic zones II, III, IV and V varies as 3.20%, 8.73%, 16.66% and 27.16% respectively.
- Thus, it is found in this study that for making a typical duplex building earthquake resistant under seismic zone II and III, hardly an additional cost of less than 4% is required. The additional cost required may be of the order of around 9% under seismic zone III of the order of around 17%under seismic zone IV. With this slight amount of additional cost, we can largely safeguard our life.
- The purpose of this project is to increase awareness about importance of earthquake resistant design of structures and to break the myth that it costs too much. The purpose is served with the above findings.

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