Structural Performance of Relief Shelf in Cantilever Retaining Wall

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Abstract: *The retaining walls (RW) are constructed to support soil laterally so, it can be retained at different levels on both sides. These are also used to bound soils and water for various heights. The cantilever retaining wall (CRW) is mainly failed due to the overturning moments, lacks of stability, unsafe designs etc. The study shows that if there is an increase in earth pressure at the backfill of the retaining walls, then there is also an increase in moments at heels. To minimize this type of effect on walls, there is a need to provide a special type of RW. So, by providing relief shelf on the backfill side of RW reduces the total earth pressure on the wall eventually it overcame with that overturning and stability problems. In this work, CRW without relief shelf and with shelf for different positioning of shelf are studied by using the GEO5 software. Total three positions at H/2, H/3, 2H/3 respectively for 1m length of relief shelf are studied. Results obtained by an analytical study of retaining walls with relief shelf (RWRS) are compared with the CRW results. Provision relief shelf to CRW gives the better stability, high safety factor reduces the active earth pressure on the wall and uses for the overall economic design of the wall than CRW.*

Keywords: **Retaining Wall, Retaining Wall with Relief Shelf, Cantilever Retaining Wall, and Safety Factors of Retaining wall, GEO5 Software.**

1. Introduction

1.1 General

Retaining wall structures are used for holding back earth material. The various reasons are for constructing the retaining walls, like preventing erosion, aesthetic purposes. The main purpose of an RW is to separate two different levels of soil or ground when there is a need for change in elevation. RW plays an important role in protecting the structures from collapsing and natural problems such as soil erosion. Earth retaining structures include CRW, sheet pilings, bulkheads, basement walls, and special types of RW. The special types of walls include counter fort RW, buttress RW, and RW that rest on piles etc. RWRS can be considered as a special type of RW. An RWRS is an uncommon type of RW. The pressure relief shelf towards the backfill side of RW helps to decrease the total earth pressure on the stem which results in increasing the overall stability of the wall. Less material is required in the stem wall due to the provision of shelves to the retaining wall, ultimately this results in the economical design. The study of RWRS is somewhat an un-noticed area in the field of Geotechnical Engineering. Very few studies are there

which have been carried out on this topic. It is observed that rarely this type of RW structure is constructed. Therefore, the study of this type of RW is very important to see the performance of such walls. The analytical and practical solutions regarding reduction in earth pressure are interesting to observe.

Chougule et al. [1] presented a manual and software analysis of the design of reinforced concrete cantilever retaining walls with single, double, and without shelves by using STAAD Pro V8i software. It states that cantilever retaining walls with two shelves is economical as compared to cantilever walls with a single shelf. Dharshan et al. [2] studied cantilever earth retaining wall of 4m height to study its optimum parameters with and without pressure relief shelf by using SAP-2000. Results exhibited that analysis and design of cantilever earth retaining wall by using software packages are easy and effective compared to manual approach and moment calculations for RWRS are less than CRW. Shinde et al. [3] studied the analysis of cantilever retaining wall using the Finite Element method with and without shelves by using Stadd-pro and results for various parameters are to be compared in this study. Dhamdhere et al. [4] conducted an analysis and design of cantilever and relieving platform retaining wall with varying height. In addition, it also highlighted the comparative study of cost, economy, bending moment, stability against overturning &sliding between both the retaining wall. Madhavi et al. [5] studied critically counterfort type retaining wall by considering six different models of RW for various parameters and crucial load cases and combinations. Shehata [6] presented a Finite Element analysis of retaining walls using PLAXIS2D-AE.01. It also presented a brief study of the effect of attaching shelves to a cantilever retaining wall. It was found that RS had a significant effect on the resulting earth pressure distribution. Karthik et al. [7] studied counterfort earth retaining wall of 8 m height for the analysis by soft computing technique in comparison with conventional RW. The different parameters such as position, the width of relief shelf, and different SBC have considered calculating the optimum parameters of counterfort earth retaining wall. Minnan et al. [10] studied the discrimination for long and short relieving platforms are deduced and the earth pressure calculation models for different relieving platforms have calculated.

The purpose of this study is to design the RW in GEO5 software & discuss the results. In this study, the CRW and RWRS are compared by considering factors such as check for overturning stability, moments at the heel of the retaining wall with & without a pressure relief shelf.

1.2 Types of Retaining Wall

There are commonly four types of RW such as Gravity RW, Semi-Gravity RW, Cantilever RW, and Counterfort RW. This study is generally focusing on the two types of RW which are as follows,

1.2.1 Details of Cantilever Retaining Wall

CRW is reinforced concrete RW along with pressure distribution as shown in figure 1. It includes a thin stem and a base slab. The base is further divided into two parts, the heel, and toe. The heel is the part of the base slab under the backfill material. The toe is the other part of the base slab.

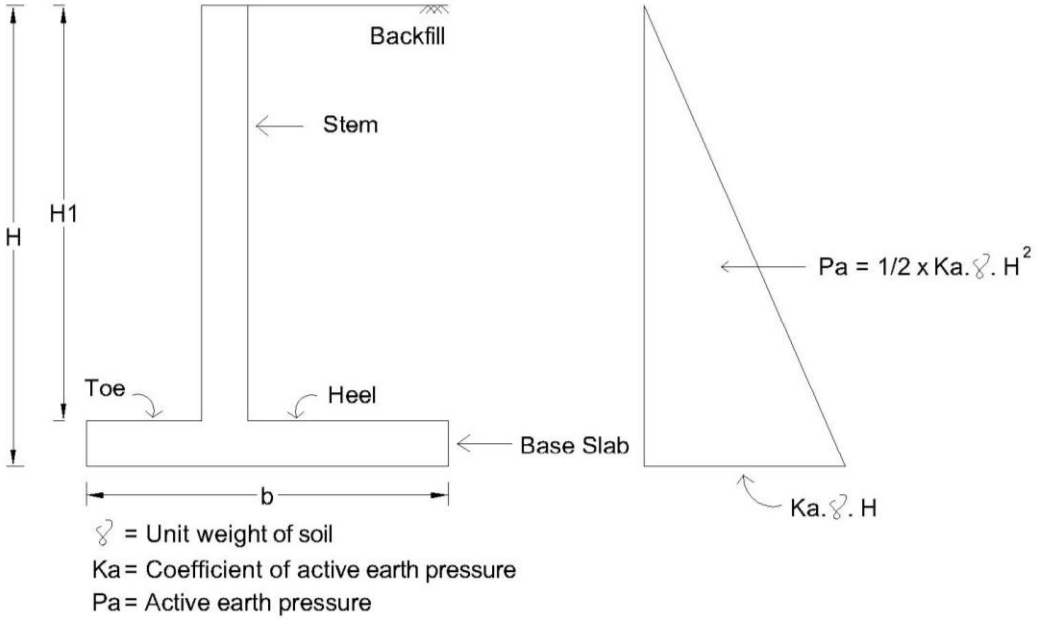

Figure 1. Pressure Distribution Diagram for Cantilever Retaining Wall (CRW)

1.2.2 Details of Retaining Wall with Relief Shelf

The type of retaining wall with relief shelf is a modification of CRW by adding relieving platform that is relief shelf (RS) as shown in figure 2. This relieving platform is provided at the stem. The platform can be one or more as design requirements. Due to the provision of this relieving platform, the pressure distribution diagram changes. Retaining the wall with this platform gives economical design as well as fewer bending moments.

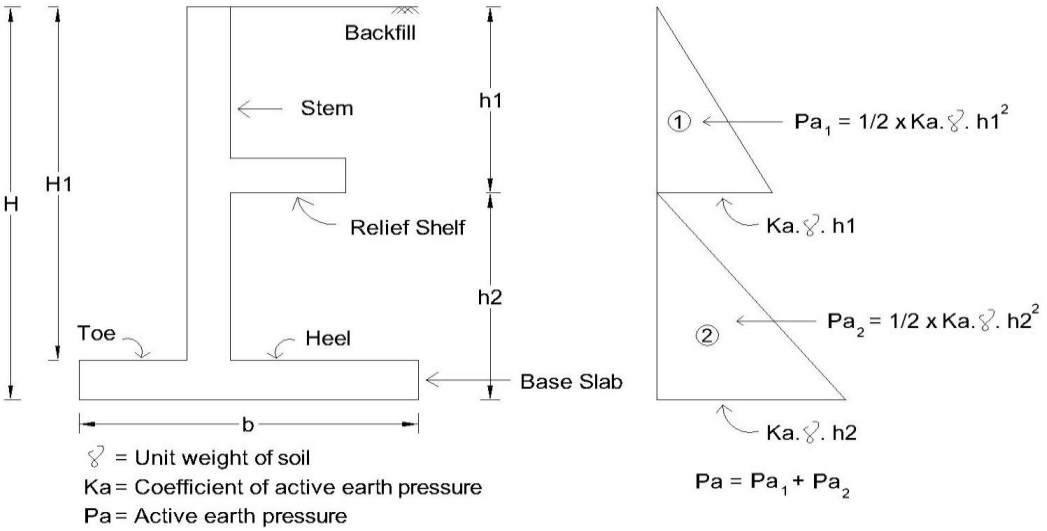

Figure 2. Pressure Distribution Diagram for Retaining Wall with Shelf (RWRS)

There are various advantages of RWRS**,** RWRS can be precast or formed on site also economical than CRW. This type of RW can be used for any height more than 8m and less than 8m**.** It reduces the lateral earth pressure on the wall. It helps to increases the overall stability of the structure. The reinforcement details of RWRS are shown in figure 3.

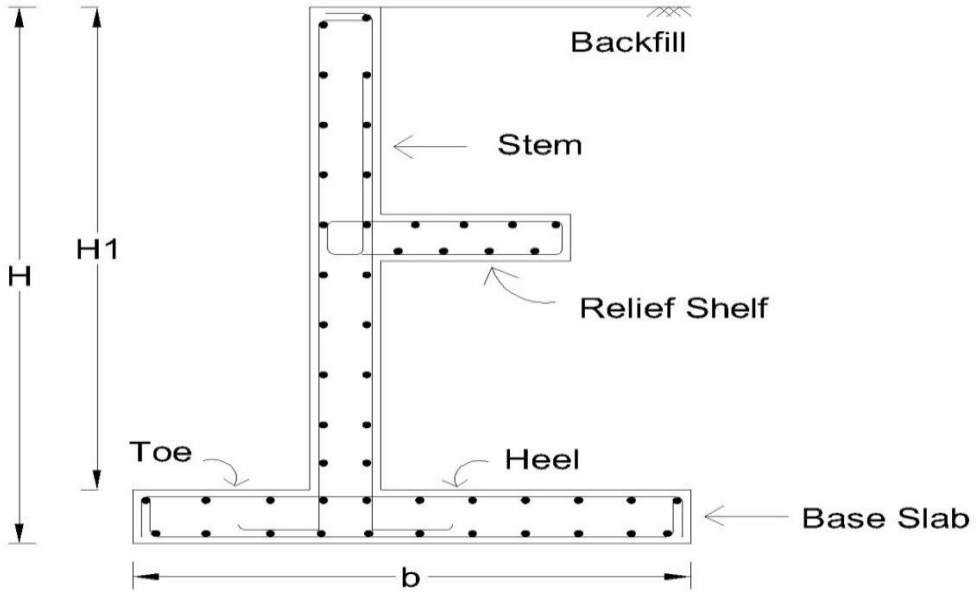

Figure 3. Reinforcement Details of Retaining Wall with Relief Shelf (RWRS)

2. Analytical Work on Retaining Wall

The designing of CRW with and without shelf is carried out as part of analytical work. The required dimensions for RW are taken into account for analysis of retaining wall behavior. The design of retaining walls is carried out in two portions as below.

A) Design of CRW of 8m height.

B) Design of RWRS of 8m height.

Design of RWRS is carried out within three cases.

a) Position of relief shelf (RS) at H/2 for 1 m length of RS.

b) Position of RS at H/3 for 1 m length of RS.

c) Position of RS at 2H/3 for 1 m length of RS.

The overturning stability and moment at the heel of RW have calculated through the design process when the shelf is provided in the retaining wall and without shelf. The design is carried out in Geotechnical Engineering software named GEO5. GEO5 is software, which provides the solution for the majority of geotechnical problems. GEO5 is important software used for solving geotechnical problems based on analytical methods and Finite Element Method (FEM). GEO5 is used to solve geotechnical problems such as

verification of foundations, walls, slope stability, up to highly specialized programs such as analysis of tunnels, building damage due to tunneling, rock stability, etc. Each GEO5 program explains a particular type of structure and is a composition of individual programs with a unified user interface.

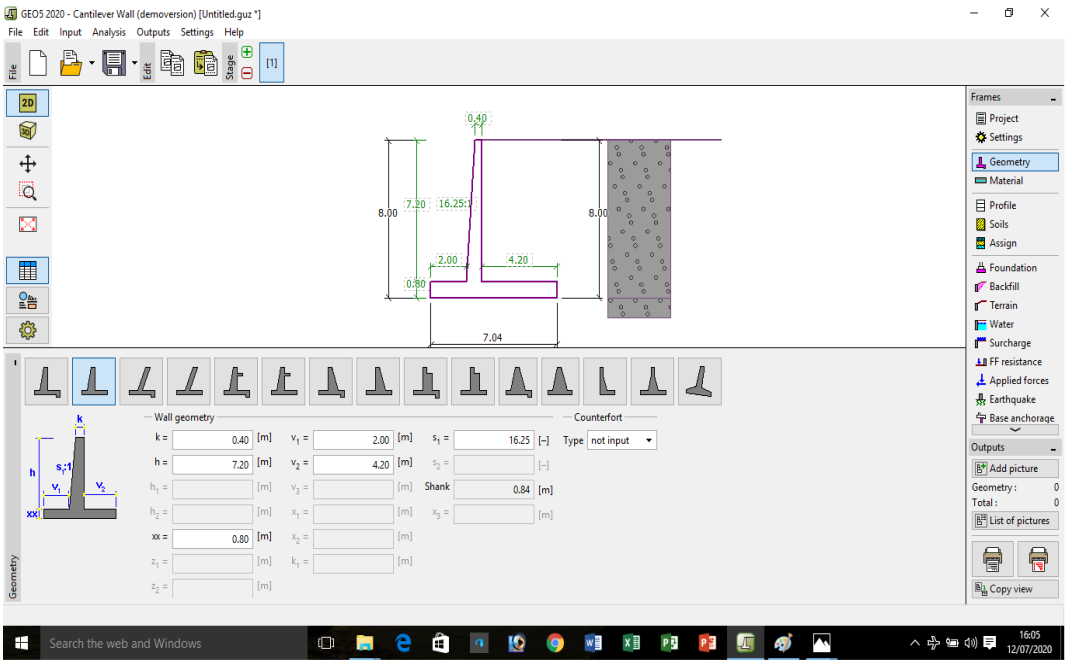

Figure 4. Dimensions of CRW in GEO5 Software

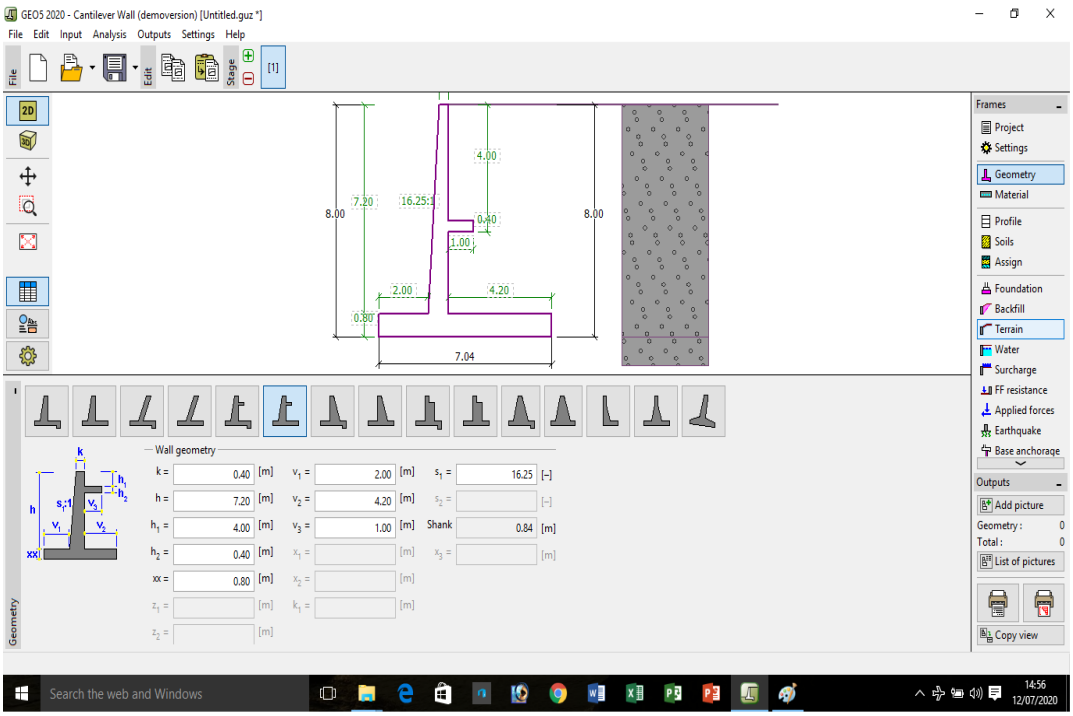

Figure 5. Dimensions of RWRS at H/2 Height for 1 m Length in GEO5 Software

2.1 Analysis and Design of Retaining Walls

The software is used to design the various earth retaining structures like RW, deep foundations, shallow foundations, sheet pile, tunnels and shafts, walls and Gabions etc. GEO5 software is also used for stability analysis, excavation design and field tests, settlement analysis etc.

2.1.1 Design Parameters

Following design parameters are incorporated in operated software while designing the CRW with and without RS as shown in table 1.

Table 1. Design Parameter for Retaining Walls

Sr. NO.	Design parameters	Quantity with unit
1	Unit weight of soil (ϒs)	20 kN/m^3
2	Angle of internal friction (ϕ)	30º
3	Coefficient of friction (ú)	0.5
4	Safe bearing capacity of soil (SBC)	200 kN/m3
5	Unit weight of Concrete	25 kN/m3
6	Grade of concrete	M20
7	Grade of steel	Fe 415

2.1.2 Dimensions of RW

1. The total design of RW is carried out for 8 m height.
2. Thickness of relief shelf is 0.40 m.
3. Thickness of base slab is 0.80 m.
4. Length of Toe is 2 m.
5. Length of heel is 4.20 m.
6. Length of RS of RW is 1m and position is varying at H/2, H/3, 2H/3.

   The dimensions of CRW & RWRS at H/2 height at 1 m. shelf length in GEO5 software is shown in figure 4. & figure 5. respectively.

3. Results and Discussions

The result of analytical work through software indicates the comparison of values of RW with and without relief shelf as well as the CRW and RWRS at H/2,H/3, 2H/3 position with 1m shelf length.

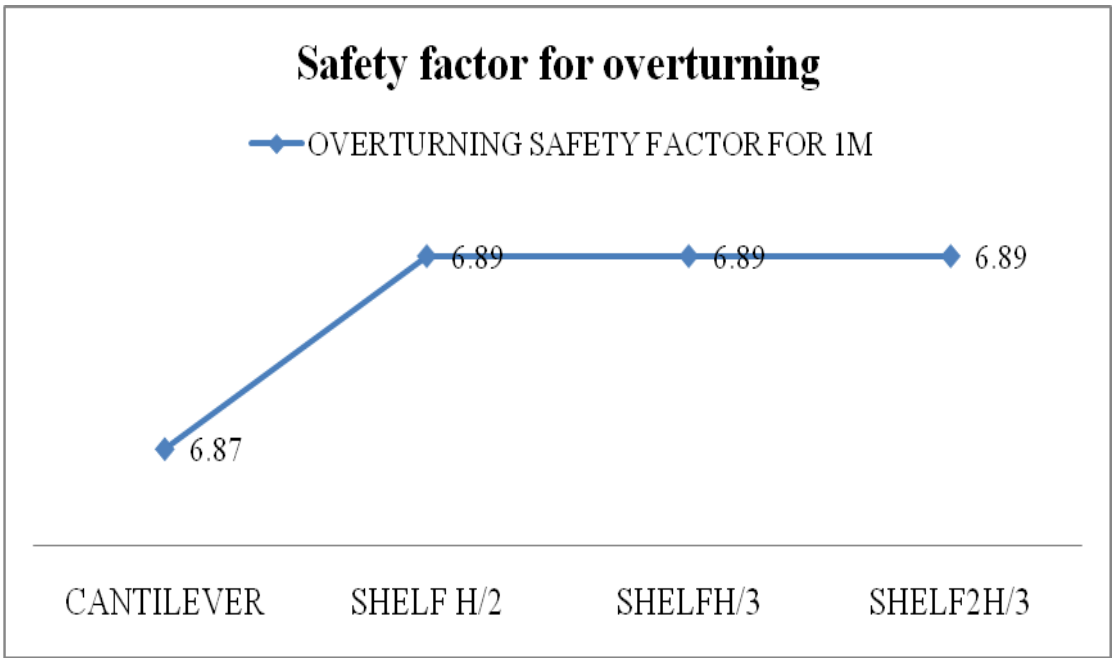

Figure 6. Safety Factor for Overturning

Figure 6. indicates the comparison of the safety factor for overturning (SFO) of RW for 1 m shelf length & CRW. The SFO for CRW is 6.87 which is minimum than the wall with shelf. The resisting moment for RW with shelf is greater than CRW for 1 m shelf length and other two positions of shelf also.

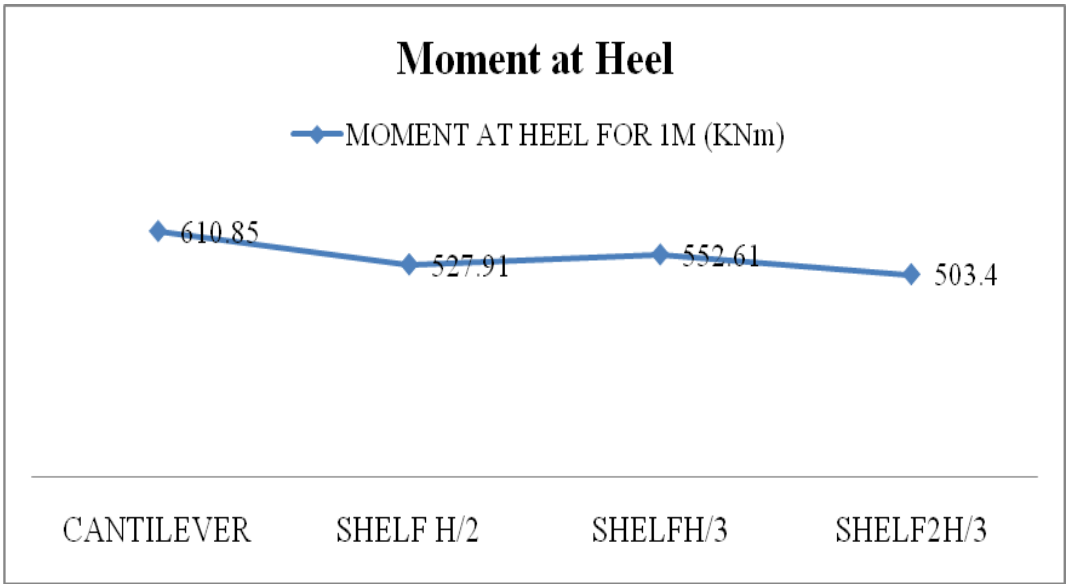

Figure 7. Moment at Heel

Figure 7. displays the comparison of moments at heel for RW with and without RS. The moment at heel for CRW is 610.85 KNm. The figure shows that the moments for RWRS at H/2, H/3, 2H/3 position is minimum than CRW. It is due to the provision of RS to the RW. The provision of shelf to the RW leads to minimum moment at heel. It also effects on to the minimum requirement of steel for heel.

4. Conclusions

The analytical study demonstrates the various results of comparison of values of RW with and without relief shelf. Three cases of RWRS are taken at H/2, H/3, 2H/3 positions with shelf length 1m. The outcomes of CRW are related to the results of different cases of RWRS. The results of RWRS are better than CRW and the following conclusions have been drawn out from the study.

1. Overturning stability check for RW at H/2, H/3 and 2H/3 positions with 1m shelf length are better than the CRW. All the three positions of RWRS are safe and give decent results as compare to CRW.
2. Moments at heel for RW at H/2, H/3 and 2H/3 position with 1m shelf length are minimum than the CRW. The position of 2H/3 with 1m shelf length gives relevant outcomes than the other two positions of shelf.
3. As per the results of 1m shelf length at H/2, H/3, 2H/3 positions, the wall with 2H/3 position is useful for design as it provides minimum moment at heel.
4. The provision of shelf to the RW leads to minimum moment at heel and reduces the steel requirement for heel which indicate the economical cross section of RW.

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