Analysis, Design And Comparison Of Rectangular And Circular Elevated Storage Tank Under Seismic Load By GSDMA Guidelines

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Abstract: Water tank can simply be explained as a container to store water in huge amount of capacity. As we know from our past experiences, these liquid storage tanks were collapsed or damaged heavily during the earthquakes all across the world. The feasible lifetime of ESR is generally in the range of 40 to 65 years. Any Damage or collapse of the tanks causes some unexpected events such as shortage of drinking water, utilizing water, uncontrolled fires etc. Water tank parameters includes various general design of tank and way of construction materials, linings etc. Various material are used for the construction of water tank like: - plastic, concrete, steel, fiber glass. Therefore, to avoid all those unwanted events in future various studies is been carried out regarding tanks. In this study, Elevated Service Reservoir (E.S.R) is being compared of Rectangular & Circular shape of 5lakh capacity and total height of 18m with 3m, 4.5m staging in Earthquake Zone V by Equivalent static analysis using STAAD.PRO software referring GSDMA guidelines for design of tank and IS 1893 PART2-2014 code. By studying all the observations various results shows that Circular water tank is more preferable and economical.

Keywords **- Elevated Service Reservoir (E.S.R), GSDMA Guidelines, Equivalent static analysis.**

I. INTRODUCTION

An elevated water tank is a large water storage container constructed for the use of holding water supply at certain height and to pressurize the water distribution system effectively. The liquid storage tanks are particularly subjected to the risk of damage, collapse due to earthquake-produced vibrations. A large number of various elevated water tanks has been damaged during past earthquake. Elevated water tanks are critical and strategic structures and any damage of these structures during the time of earthquakes may endanger drinking water supply, cause to fail in preventing large fires in the areas and substantial economic loss etc. Since, the elevated tanks are commonly used in earthquake prone regions hence, seismic properties of them have to be investigated in full details.

TYPES OF WATER TANKS

In present year, there has been much stress on water supply extends everywhere throughout the world, which are exceptionally essential for the social and modern improvement of the nation. Capacity difference of water tanks can be accessible relying on the necessity of utilization. The water tanks are classified based on shape:

a. Rectangular tanks
b. Circular tanks
c. Intze tanks
d. Spherical tanks
e. Circular tank with conical bottom.

Also, there is three ways of water tanks classified based on the location:

a. Tank resting on grounds
b. Underground water tanks
c. Elevated or overhead water tanks.

II. WATER TANKS MODEL ANALYSIS

For Case 1: Comparative study of rectangular and circular tank (using circular column with 18mts height and 3-3 mts staging)

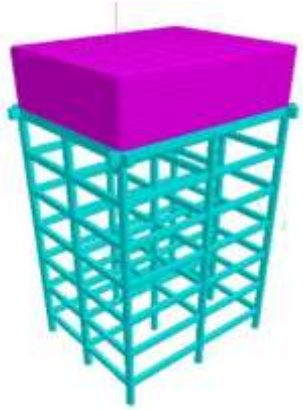

Fig 1: Overhead Rectangular Tank

Fig 2: Overhead Circular Tank

Above figure shows the 3D image of overhead rectangular and overhead circular tank with circular columns. Both the tanks have 18meters of column height and 3-3 meters of staging. There are 9 no of columns in rectangular water tank and 5 no of columns in circular water tanks which can be seen clearly in this 3D image.

General specifications:-

Parameters of Water Tank shown in fig 1(Overhead Rectangular tank), fig 2(Overhead Circular tank) and details as given below:

Grade of concrete & steel in rectangular water tank is M-30 & FE-500 and in circular water tank is M-30 & FE-500. Volume of tank in rectangular water tank is 500 cum or 500000 LTS and in circular water tank is 500 cum or 500000 LTS. Height of water stored as per tender clause in rectangular water tank is 4mts and in circular water tank is 4 mts. Free board in rectangular water tank is 0.2 mts and in circular water tank is 0.2 mts. Height of tank in rectangular water tank is 18 MTS and in circular water tank is 18 MTS. Total height of wall in rectangular water tank is 4.2 MTS and in circular water tank is 4.2 MTS. Plan area/dia OF circular tank in rectangular water tank is 12.5X10.5 MTS and in circular water tank is 12.6 MTS. Total no of columns in rectangular water tank is 9 and in circular water tank is 5. Sizes of column (circular) 0.50X0.50 MT2in rectangular water tank is 0.50X0.50 MT2. Bottom of foundation in rectangular water tank is 2 MTS and in circular water tank is 2 MTS. Plinth beam size in rectangular water tank is 0.25X0.5 MT2 and in circular water tank is 0.25X0.5 MT2. Floor beam size in rectangular water tank is 0.3X0.7 MT2 and in circular water tank is 0.3X0.7 MT2. Floor slab thickness in rectangular water tank is 0.25 MTS and in circular water tank is 0.25 MTS. Thickness of gallery in rectangular water tank is 0.1 MTS and in circular water tank is 0.1 MTS. Size of bracings in rectangular water tank is 0.25X0.50 MT2 and in circular water tank is 0.25X0.50 MT2.

For Case: 2 Comparative study of rectangular and circular tank (using rectangular column with 18mts height and 3-3 mts staging)

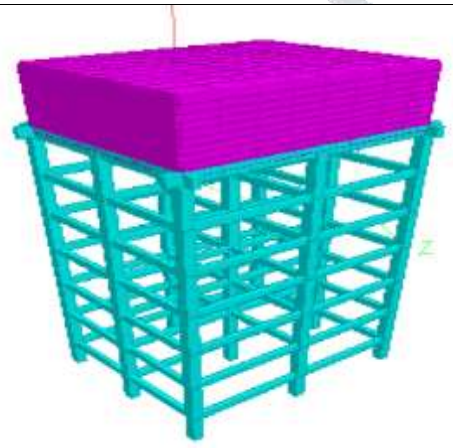

Fig :3 Overhead Rectangular Tank

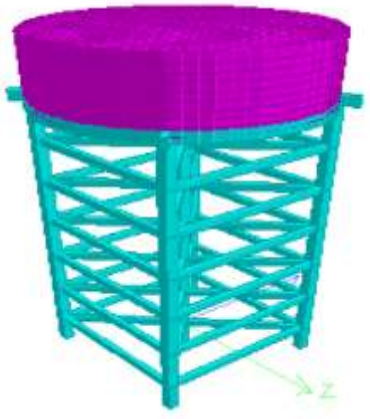

Fig :4 Overhead Circular Tank

Above figure shows the 3D image of overhead rectangular and overhead circular tank with rectangular columns. Both the tanks have 18meters of column height and 3-3 meters of staging. There are 9 no of columns in rectangular water tank and 5 no of columns in circular water tanks which can be seen clearly in this 3D image

General specifications: -

Parameters of Water Tank shown in fig 3(Overhead Rectangular tank), fig 4(Overhead Circular tank) and details as given below:

Grade of concrete & steel in rectangular water tank is M-30 & FE-500 and in circular water tank is M-30 & FE-500. Volume of tank in rectangular water tank is 500 cum or 500000 LTS and in circular water tank is 500 cum or 500000 LTS. Height of water stored as per tender clause in rectangular water tank is 4mts and in circular water tank is 4 mts. Free board in rectangular water tank is 0.2 mts and in circular water tank is 0.2 mts. Height of tank in rectangular water tank is 18 MTS and in circular water tank is 18 MTS. Total height of wall in rectangular water tank is 4.2 MTS and in circular water tank is 4.2 MTS. Plan area/dia OF circular tank in rectangular water tank is 12.5X10.5 MTS and in circular water tank is 12.6 MTS. Total no of columns in rectangular water tank is 9 and in circular water tank is 5. Sizes of column (circular) 0.50 MT2 in rectangular water tank is 0.50 MT2. Bottom of foundation in rectangular water tank is 2 MTS and in circular water tank is 2 MTS. Plinth beam size in rectangular water tank is 0.25X0.5 MT2 and in circular water tank is 0.25X0.5 MT2. Floor beam size in rectangular water tank is 0.3X0.7 MT2 and in circular water tank is 0.3X0.7 MT2. Floor slab thickness in rectangular water tank is 0.25 MTS and in circular water tank is 0.25 MTS. Thickness of gallery in rectangular water tank is 0.1 MTS and in circular water tank is 0.1 MTS. Size of bracings in rectangular water tank is 0.25X0.50 MT2 and in circular water tank is 0.25X0.50 MT2.

For Case: 3 Comparative study of rectangular and circular tank (using column with 18mts height and 4.5-4.5 mts staging)

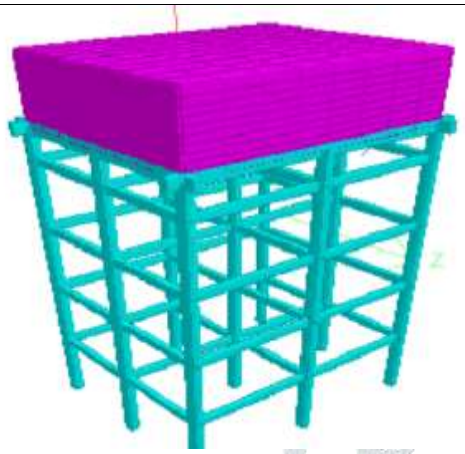

Fig :5 Overhead Rectangular Tank

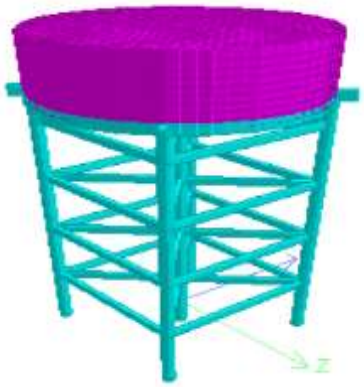

Fig :6 Overhead Circular Tank

Above figure shows the 3D image of overhead rectangular and overhead circular tank with circular columns. Both the tanks have 18meters of column height and 4.5-4.5 meters of staging height. There are 9 no of columns in rectangular water tank and 5 no of columns in circular water tanks which can be seen clearly in this 3D image.

General specifications: -

Parameters of Water Tank shown in fig 5(Overhead Rectangular tank), fig 6(Overhead Circular tank) and details as given below:

Grade of concrete & steel in rectangular water tank is M-30 & FE-500 and in circular water tank is M-30 & FE-500. Volume of tank in rectangular water tank is 500 cum or 500000 LTS and in circular water tank is 500 cum or 500000 LTS. Height of water stored as per tender clause in rectangular water tank is 4mts and in circular water tank is 4 mts. Free board in rectangular water tank is 0.2 mts and in circular water tank is 0.2 mts. Height of tank in rectangular water tank is 18 MTS and in circular water tank is 18 MTS. Total height of wall in rectangular water tank is 4.2 MTS and in circular water tank is 4.2 MTS. Plan area/dia of circular tank in rectangular water tank is 12.5X10.5 MTS and in circular water tank is 12.6 MTS. Total no of columns in rectangular water tank is 9 and in circular water tank is 5. Sizes of column (circular) 0.60 MT2 in rectangular water tank is 0.60 MT2. Bottom of foundation in rectangular water tank is 2 MTS and in circular water tank is 2 MTS. Plinth beam size in rectangular water tank is 0.25X0.5 MT2 and in circular water tank is 0.25X0.5 MT2. Floor beam size in rectangular water tank is 0.3X0.7 MT2 and in circular water tank is 0.3X0.7 MT2. Floor slab thickness in rectangular water tank is 0.25 MTS and in circular water tank is 0.25 MTS. Thickness of gallery in rectangular water tank is 0.1 MTS and in circular water tank is 0.1 MTS. Size of bracings in rectangular water tank is 0.25X0.50 MT2 and in circular water tank is 0.25X0.50 MT2

III. RESULTS AND DISCUSSION

For Case 1: After Analyzing E.S.R. from Staad Pro having parameters, following results and outcomes are carried out which is shown below in results and discussions

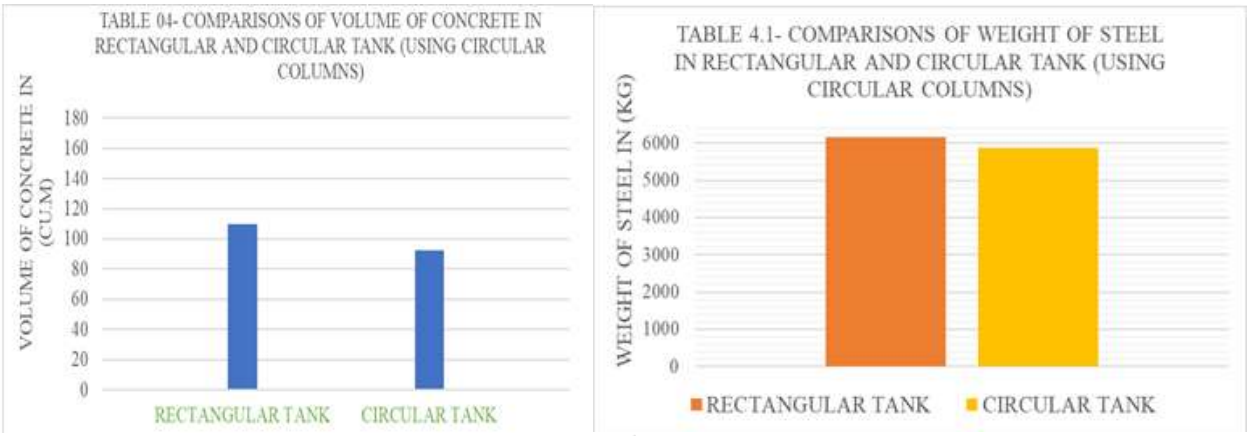

Fig shows the amount of steel and concrete required

Amount of Steel and Concrete Required

These two graphs show 1) Total Volume of Concrete in rectangular and in circular water tank required and 2) shows Total Weight of Steel in rectangular kg and in circular water tank required. X axis shows rectangular and circular tanks in different color while Y axis shows volume of concrete in (cum) and weight of steel in (kg). Total Volume of Concrete in rectangular water tank is 109.8 m3 and in circular water tank is 92.6 m3. Total Weight of Steel in rectangular water tank is 6164 kg and in circular water tank is 5870 kg.

Base shear, Base moment and Time period

Base shear in impulsive mode (kN) in rectangular water tank is 303 and in circular water tank is 222. Base shear in Convective Mode (kN) in rectangular water tank is 109 and in circular water tank is 115. Total Shear to be applied at the CG of tank (kN) in rectangular water tank is 323 and in circular water tank is 250. Overturning moment at the base of staging in impulsive mode (kN-m) in rectangular water tank is 6490 and in circular water tank is 4735. Overturning mode at the base of staging in Convective Mode (kN-m) in rectangular water tank is 2844 and in circular water tank is 2890. Total Overturning Moment (kN-m) in rectangular water tank is 7086 and in circular water tank is 5547. Time period in Impulsive Mode (Ti) (sec) in rectangular water tank is 1.46 and in circular water tank is 1.84. Time period in Convective Mode (Tc) (sec) in rectangular water tank is 3.87 and in circular water tank is 4.10.

Plate Stress:

Plate stresses can simply be explained as the bending of plates due to application of loads on the plates results in the deflection of plates and these stresses in the plate can be calculated from these deflections. Once the stresses acting on plates are known, then failure theories can be applied to find out whether these plates will fail under a given load or not.

S.no	Type of tank	**SQX** (n/mm^2)		**SQY**(n/mm^2)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-0.402	0.190	-1.470	0.915
2	Circular	-2.856	0.697	-0.598	0.395

Table 1: LOCAL SHEAR STRESS VALUES

Above table explains about the plate stresses introduced in rectangular as well as circular water tanks. Different results were found out and after analyzing the following results, we can clearly say that circular water tanks are getting lower values of stresses. In this we clearly see that stresses value are also getting lower for circular tank case type.

For Case 2: After Analyzing E.S.R. from Staad Pro having parameters, following results and outcomes are carried out which is shown below in results and discussions.

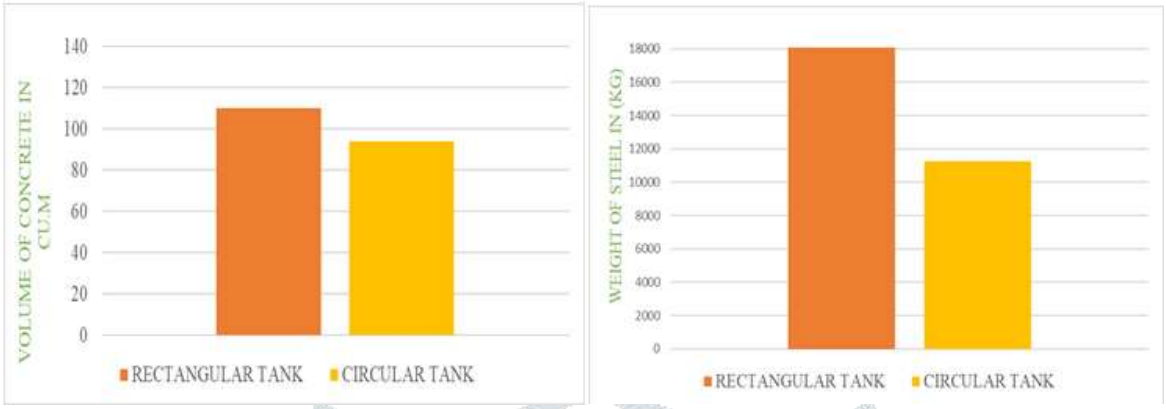

Fig shows the amount of steel and concrete required

Amount of Steel and Concrete Required

These two graphs show 1) Total Volume of Concrete in rectangular and in circular water tank required and 2) shows Total Weight of Steel in rectangular kg and in circular water tank required. X axis shows rectangular and circular tanks in different color while Y axis shows volume of concrete in (cum) and weight of steel in (kg). Total Volume of Concrete in rectangular water tank is 110 m3 and in circular water tank is 94 m3. Total Weight of Steel in rectangular water tank is 18056 kg and in circular water tank is 11270 kg.

Base shear, Base moment and Time period

Base shear in impulsive mode (kN) in rectangular water tank is 303 and in circular water tank is 222. Base shear in Convective Mode (kN) in rectangular water tank is 109 and in circular water tank is 115. Total Shear to be applied at the CG of tank (kN) in rectangular water tank is 323 and in circular water tank is 250. Overturning moment at the base of staging in impulsive mode (kN-m) in rectangular water tank is 6490 and in circular water tank is 4735. Overturning mode at the base of staging in Convective Mode (kN-m) in rectangular water tank is 2844 and in circular water tank is 2890. Total Overturning Moment (kN-m) in rectangular water tank is 7086 and in circular water tank is 5547. Time period in Impulsive Mode (Ti) (sec) in rectangular water tank is 1.46 and in circular water tank is 1.84. Time period in Convective Mode (Tc) (sec) in rectangular water tank is 3.87 and in circular water tank is 4.10

Shows the variation in plate stresses value (Final value)

S.no	Type of tank	**SQX** (n/m**m**^{2})		**SQY**(n/mm^2)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-0.138	0.189	-0.018	0.159
2	Circular	-0.316	0.429	-0.57	0.60

Table 2: LOCAL SHEAR STRESS VALUES.

Shows the variation in plate stresses value (With respect to moments along mention axis)

S.no	Type of tank	**MX** (KNm/m)		**MY** (KNm/m)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-103.2	94.1	-100	88.2
2	Circular	-90.3	58	90	57

Table 3: LOCAL SHEAR STRESS VALUES.

Above table explains about the plate stresses introduced in rectangular as well as circular water tanks. Different results were found out and after analyzing the following results, we can clearly say that circular water tanks are getting lower values of stresses. In this we clearly see that stresses value are also getting lower for circular tank case type.

For Case 3: After Analyzing E.S.R. from Staad Pro having parameters, following results and outcomes are carried out which is shown below in results and discussions.

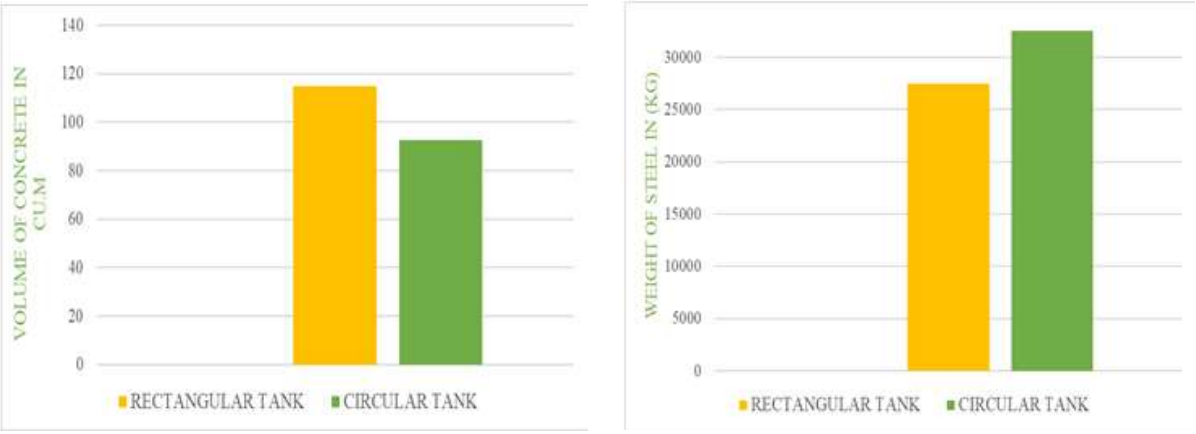

Fig shows the amount of steel and concrete required

Amount of Steel and Concrete Required

These two graphs show 1) Total Volume of Concrete in rectangular and in circular water tank required and 2) shows Total Weight of Steel in rectangular kg and in circular water tank required. X axis shows rectangular and circular tanks in different color while Y axis shows volume of concrete in (cum) and weight of steel in (kg). Total Volume of Concrete in rectangular water tank is 110 m3 and in circular water tank is 94 m3. Total Weight of Steel in rectangular water tank is 18056 kg and in circular water tank is 11270 kg.

Base shear, Base moment and Time period

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Shows the variation in plate stresses value (Final value)

S.no	Type of tank	**SQX** (n/mm^2)		**SQY**(n/mm^2)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-0.138	0.189	-0.018	0.159
2	Circular	-0.316	0.429	-0.57	0.60

Table 4: LOCAL SHEAR STRESS VALUES.

Above table explains about the plate stresses introduced in rectangular as well as circular water tanks. Different results were found out and after analyzing the following results, we can clearly say that circular water tanks are getting lower values of stresses.
In this we clearly see that stresses value are also getting lower for circular tank case type.

Shows the variation in plate stresses value (With respect to moments along mention axis)

S.no	Type of tank	**MX** (KNm/m)		**MY** (KNm/m)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-103.2	94.1	-100	88.2
2	Circular	-90.3	58	90	57

Table 5: LOCAL SHEAR STRESS VALUES.

In above figures or table, we can clearly see that even after changed bracing from 3 to 4.5 mts there is no change in stresses or moment along axis, reason behind it is that staging/bracing height has no connections regarding bottom of slab of tank it is connected or regarded with columns positions and total height of the tanks, so its final implementation doesn't affect the stresses or moment behavior of tank.

IV. CONCLUSION

Case 1:

1. Circular water tanks are found to be more economical than rectangular water tank.
2. Total base shear for circular tank is less than rectangular tank.
3. Total overturning moment for circular tank is less than rectangular tank.
4. As per table 9, it can be said that in most of the region/cases plate stress are found to be less in case of circular tanks

Case 2:

1. By replacing circular column to rectangular columns, Circular water tank are found to be more economical than rectangular water tank.
2. Total base shear for circular tank is less than rectangular tank.
3. Total overturning moment for circular tank is less than rectangular tank.
4. As per table 12 it can be said that in most of the region/cases plate stresses and moments are found to be less in case of circular tanks

Case 3:

1. By replacing 3.5mt bracings to 4.5 mts using circular columns, Circular water tank are found to be more economical than rectangular water tank.
2. Total base shear for circular tank is less than rectangular tank.
3. Total overturning moment for circular tank is less than rectangular tank.
4. As per table 16 it can be said that in most of the region/cases plate stress are found to be less in case of circular tanks
5. Soil pressure intensity is less in piled raft foundation as compare to raft foundation.

Acknowledgments

I would like to thank first my project guide Prof. Amey R. Khedikar for their guidance and invaluable words of advice, support and help given to me to do this review paper. Secondly, I would like to thank my parents and friends for their appreciation and belief in me.

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