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A Case Study on Performance of Confined Composite Pavement in Dharwad Town of Karnataka, India.

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Abstract

The roadway is the most important means of communication for transporting people and materials. It has been observed that due to the lateral deformation and lack of edge confinement pavement gets deteriorated. As per the "Indian Motor Vehicle Act and Rules", In India, the right-hand drive side system vehicles are required to follow the left lane of the road in both directions [1]. Conversely, in many western countries, left-hand drive system vehicles are required to follow the right side of the road in both the "up" and "down" directions according to their motor vehicle act and rules. These regulations compel vehicles to travel on the roads within a specific track known as the wheel track, except during overtaking situations. Generally, the minimum horizontal distance from the edge of the road to the wheel track is 300mm to 500mm in both directions. This side clearance provides safety and comfort for the driver while maneuvering the vehicle. Oftentimes, the repeated wheel loading on this strip of side clearance causes the pavement to predominantly fail at the edges. So, it calls for a special design for the edges of flexible pavements to make them stable and durable. In view of this, it is evident that there needs to strengthen the pavement edges instead of merely providing simple shoulders against lateral deformation. Hence an attempt is made in this direction for the road called "Karnataka College Road" in Dharwad town, Karnataka, India by providing confinement to the composite pavement edges. The results are encouraging and the performance of the road is very good without showing any sort of structural failure.

Index terms: **Confinement; lateral deformation; motor vehicle act; Composite pavement, performance.**

I INTRODUCTION

The roadway communication all over the world is gaining more and more importance because of its ease of speedy construction, cost effectiveness, ease of widening, less repair and rehabilitation and maintenance cost to cope up with the rapid increase in traffic volume. India has about 63.73lakh km of road network as on 30th November 2022 which is the second largest in the world. The lengths of different categories of roads are National Highways (NH) – 1,44,634km, State Highways (SH)– 1,86,908km and other roads – 59,02,539km. The growth of NH from 2014-15 up to 2022-23 is increased to 47.85% [1]. In addition to the new construction of roads, the cost of repair, rehabilitation and maintenance of the roads constructed many years ago has become expensive. Most of the highway fund is being spent on these old roads. In recent years the construction of rigid pavements is gaining more and more importance because of its lifetime cost effectiveness, no maintenance or very little maintenance, riding comfort, visibility at night etc. But looking at its disadvantages like high cost of repair, reduction in ground water table due to its impervious nature, restrictions to provide underground utility ducts, wear, and tear of vehicles' tyres due to high friction with anti-skid surface texture and sound pollution, the present trend is to construct composite pavements. The composite pavement constructed with flexible pavement adjoining the rigid pavement on both the sides of the road allows for providing underground utility ducts even in future. The composite pavements can also be cost effective during capital investments in lieu of complete rigid pavements. In case of multi lane roads, it may be feasible to construct rigid pavements for the heavy vehicle lanes and flexible pavements for light motor vehicles. As the speed of the heavy vehicles will generally be less compared to the light vehicles the wear and tear of tyres and the noise pollution will be less for heavy vehicles compared to that of light vehicles moving on rigid pavements. Even if a rigid pavement needs to be constructed in future in the portion of existing flexible pavement while widening the road for the increased traffic volume, white topping can be laid without disturbing the foundation of the existing flexible pavement. Therefore, the composite roads provide flexibility to widen the road and also to confine the rigid pavement from lateral deformation.

II LITERATURE REVIEW.

Shamil Ahmed Flamarz and Al-Arkawazi (2017) [1]. Authors have discussed the factors considered for the design of flexible pavement such as traffic volume, Climatic condition, road geometry, location, type of soil subgrade and surface and subsurface drainage. They classified the pavement failures or deteriorations mainly in four groups like, surface deformation, cracking, disintegration, and surface defects. IRC-106-Guidelines-for-capacity-of-urban-roads-in-plain-areas (1990) [2]. The number of lanes of roads depends on the traffic volume and other parameters of the road at the time of planning and designing. Therefore, the capacity analysis is the basic requirement in planning, designing and operation of roads. Undivided urban roads are known as 2-lane undivided (two way), 3-lane undivided, 4-lane undivided and 6-lane undivided depending on the number of land available for the use of traffic. In the similar way divided roads are known as 4, 6 and 8 lane divided (one way traffic) roads. IRC: SP:73-(2007) [3]. The common deterioration of the edges of the pavement is due to nonconfinement of the edges without the proper construction of the paved shoulders for a width of 1.5m and to the thickness equal to the thickness of the adjacent existing pavement. Yaning Qiao, Andrew R. Dawson, Tony Parry, Gerardo Flintsch and Wenshun Wang (2020) [4]. The authors have discussed the climate impacts on the deterioration rate, maintenance and life cycle cost of both flexible pavement and rigid pavements. The direct and indirect impact of climate change needs to be considered at the design stage of flexible pavements. Climate change not only impacts the deterioration of the pavement but also contributes to the environmental impacts. The emission of Greenhouse Gases (GHG) to the extent of 25% of total domestic GHG are from highway users. Various studies have proved that the effect of temperature compared to the effect of other factors is the most influential for flexible pavement performance. Abolfazl Hassani, Mohammad Taghipoor and Mohammad M. Karimi (2020) [5]. have emphasized on a new concept of constructing Semi-Flexible Pavement (SFP). The technology consists of flexible pavement with open graded asphalt concrete with a high air void content which will be filled by injecting special grouting materials. There will be no expansion, contraction, and construction joints in SFP, proving it to be good in resisting rutting, shoving, corrugations. These SFPs will have both flexible characteristics asphalt pavement and the high strength rigid pavement. Jorge G and Zornberg (2017) [6], use geosynthetics in flexible pavements at different levels like subgrade subbase interface, subbase base interface, base binder (wearing course of original pavement) interface and between original wearing coat and the overlay. It demonstrates the use of geosynthetics as reinforcement in original construction and overlay of pavements. So, the geo synthetics can be used as separation layer, filtration, reinforcement, stiffening and lateral drainage layer. These properties help in enhancing the sustainability and durability of the pavement. Ralph Haas, Jamie Wallsand R. G. Carroll. Department of Civil Engineering, University of Waterloo [7]. The mechanism of geogrid reinforcement in the base granular layer is studied through analysis of stress, strain, and deflection measurements. In this study the very purpose is to explain the mechanism of geogrid reinforcement in the base granular layer through analysis of stress, strain, and deflection measurements. They have reported that the reinforcing material should have high tensile modulus to resist stretching the under load, dimension stability to resist radial stresses without deforming, warping, and elastic deformation under dynamic loading. They advocated for providing geogrid at base-subgrade interface. The important outcome of this study is that no benefits are expected when a single layer of geogrid is placed within the zone of compression such as near the top of base layer under an asphalt concrete surface or within the base layer of thick bases over very soft flexible subgrade.

III HISTORY OF THE ROAD UNDER STUDY.

The Hubballi Dharwad is a twin city having a municipal corporation serving the large population of about 12,04,500lakh. The road infrastructure is a key component of the communication system for socioeconomic development of urban areas. Since the road named “Karnataka College Road from Jubilee Circle to Karnataka College of Arts, Commerce and Science” in Dharwad was chosen by the Government of Karnataka, India for reconstruction as this road used as an arterial route for the citizens accessing the central marketing place called Subhas Road, famous Karnataka University, and adjoining towns. The length of the road is 1121.91m. The condition of the road chosen for improvement was very pathetic and was not under motorable condition. It often requires frequent repair due to heavy urban traffic.

3.1 Condition of the road prior to improvement:

The capacity of the road was insufficient looking at the local urban traffic volume. There was a two-way asphalted road with a small median having variable width of about 5.0m on both up and down directions. Side compound walls of private properties were abutting the road. There was no proper surface and subsurface drainage system. The rain water used to be stagnant at many places due to which the road was suffering with potholes, depressions, rutting and differential settlement. But as the road is urban road having many underground (UG) utility ducts, in order to protect the UG ducts and for the ease of repair and renovation, it was proposed to provide rigid pavement of 3750mm on both sides from the median of 600mm and 1800mm flexible pavement on both ends abutting to rigid pavement. So, the government of Karnataka decided to take up this work for rehabilitation accordingly. Government administratively approved and sanctioned the work for INR 270,00, 000=00.The tender was awarded to M/s. Shivakumar S. Police Patil and Company for a tendered amount of INR 303,51,271=00 @15% above. But the government decided to construct a single lane with 3750mm on either side from the center line and then flexible pavement for a width of 1800m at both the ends.

So, as per the new proposal the estimate was revised and it was estimated an excess amount of INR 14,16,712.00 was to be paid to the bidder. The work was executed for a total amount of INR 442,74,00,000=00 as there was delay in the process and escalation in rates.

3.2 Design of pavements:

Data:

The road being a composite road having both flexible and rigid pavements, both the pavements are designed as per IRC:37 and IRC:58 respectively.

Table 1 provides traffic census details collected during the year 2008.

Table 1: Details of traffic census

Type of vehicle	No of vehicles per day in up direction	No of vehicles per day in down direction
Two axles	1279	922
Three axles	171	124
Multi axel	41	17
Total	**1491**	**1063**

Parameters considered for the design are depicted in Table 2.

Table 2: Design parameters.

Sl. No.	Description	Value
1	No of commercial vehicles in one direction (CVPD) = P =	1491
2	Annual rate of growth of traffic (r)	7.5%
3	Period of completion in years (x)	2
4	Initial traffic at the time of completion (A) = P $(1+r)^x$	1723.03
5	Design life considered in years (n)	30
6	Lane distribution factor (D) for two lanes	75%
7	Vehicle damaging factor (F)	3.5
8	Average California Bearing Ratio (C.B.R)	6%

3.2.1 Design of flexible pavement:

Million standard axles (m.s.a) N = {365*A*[(1+r) n-1] *D*F}/r = 147.77

The average C.B.R values is 6%. Therefore, as per Plate 2 para 4.2.11 / Page 33 of IRC:37 the total thickness required is 720 mm. Accordingly the provisions were finalized based on the existing road condition as shown in Table 3.

Table 3: Existing and proposed flexible pavement courses.

Existing thickness in mm		Scarified thickness in mm	Proposed thickness in mm		Remarks
Wearing coat	25	25	SDBC	25	Designed thickness is 720mm. Hence ok
W.B.M	125	30	B.M	50	
Subgrade	150	0	W.M.M	275	
Balance	525	275	G.S. B	150	
			Balance existing	**275**	
			Total	**720**	

3.2.2 Design of rigid pavement.

IRC:58 is adopted and parameters considered are shown in Table 4

Table 4: Design parameters of rigid pavement

Sl. No	Description	Value
1	No of commercial vehicles in one direction (CVPD) = P =	1491
2	Annual rate of growth of traffic (r)	7.5%
3	Design life considered in years (n)	30
4	Cumulative repetitions in 30 years C = $\{365*A*[(1+r)^n-1]\}/r$	56295110
5	Design is for two lane for two way so 25% of C value is considered for design as per clause 4.4 of IRC:58	14073778 Or 14.07×10^6 Repetitions
6	Subgrade modulus (K) However, “K” value considered for design	$16.6 kg/cm^2/cm$ 10
7	Modified subgrade modulus is proposed for Dry Lean Concrete	Bade course
8	Modulus of rupture of flexural strength for C.C. M40	$4.5 N/mm^2$
9	Load safety factor	1.10
10	Assumed thickness of Pavement Quality Concrete (PQC) in mm	240
11	Grade of concrete	M40

As the front axles of vehicles carry much lower load compared to rear axles, only rear axles are considered for design as per appendix 2 of IRC:58 / P-54. The design outputs are shown in Table 5

Table 5: Design output

Sl.No	Description	Designed value	Acceptable value	Comment	Reference
1	Cumulative life consumed as computed	0.98	Up to 1.00	Hence ok	Clause 5.4 of IRC:58
2	Total stress due to warping and highest axle load	4.209N/mm^2	4.50N/mm^2	Hence ok	Flexural strength is 4.5N/mm2 for M40
3	Corner stress	15.50N/mm^2	4.50N/mm^2	Hence ok	Flexural strength is 4.5N/mm2 for M40
4	Joints Longitudinal joints Transverse joints	Provided Provide @ 4.5m interval	To be provided for two lanes. To be provide as contraction and construction joints	Hence ok	As per IRC:58 as single lane is provided and adjoining lane is flexible pavement no tie bars are suggested
5	Dowel bars M.S rods 25mm diameter	405mm Provided 500mm @25mm c/c	As per design	Hence ok	As per design

The provisions for rigid pavement were designed based on the existing road condition to match with the adjoining flexible pavement (Table 6).

Table 6: Existing and proposed rigid pavement design

Existing thickness in mm		Proposed thickness in mm		Remarks
Wearing coat	25	PQC	240	Designed thickness is 720mm. Hence ok.
W.B.M	125	D.L.C	100	
Subgrade	150	G.S.B	150	
		Subgrade and WMM	230	
		Total	**720**	

The details of the road cross section and longitudinal section with pavement quality concrete (PQC) rigid pavement and Black topped (B.T-flexible pavement) are shown in the Figure 1 and Figure 2.

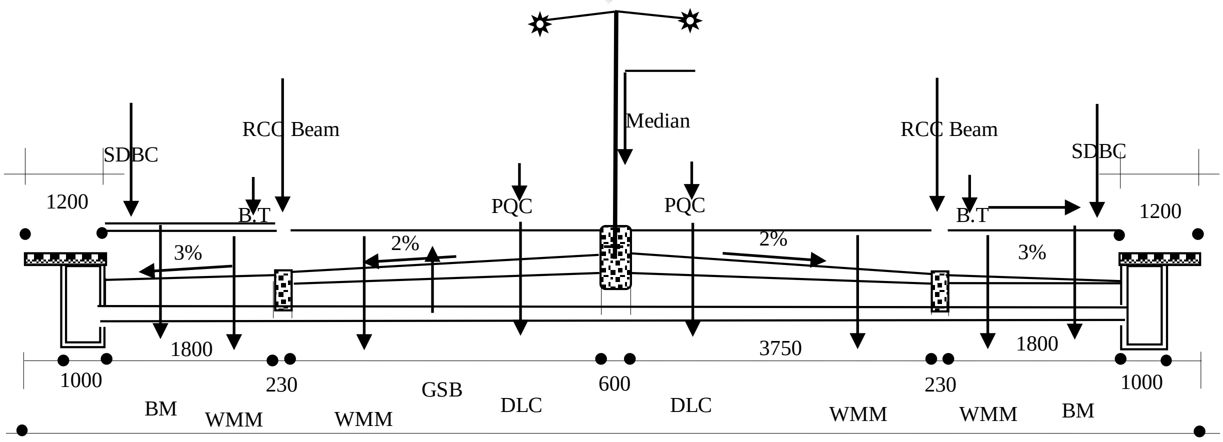

Fig.1: Cross section of composite

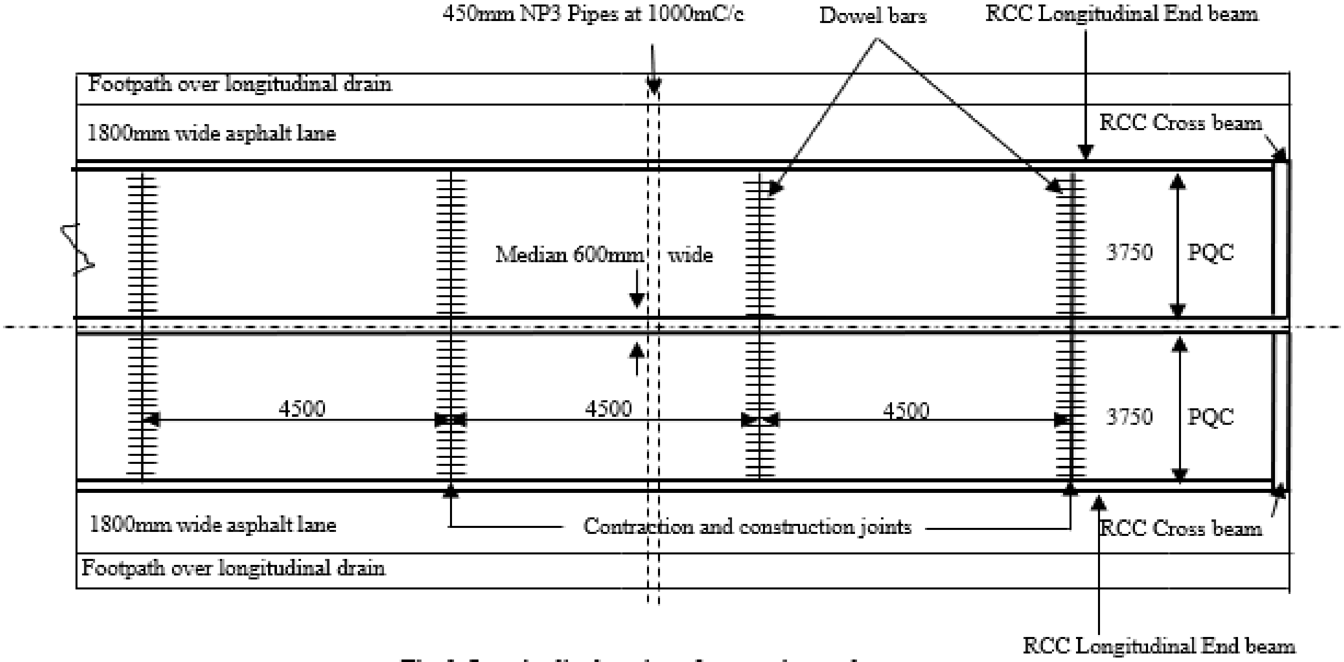

Fig. 2: Longitudinal section of composite road

3.2.3 The construction of composite road:

The road is constructed as a composite road with both rigid and flexible pavement constructed side by side. The perfect confinement of the edges of both rigid and flexible pavements enhances the stability and the durability of the road. The RCC beams provided at the longitudinal edges and cross beams at the ends of rigid pavement up to the G.S.B, provide stability to the pavement against lateral deformation of the sub layers. The provision of RCC median at the center of the road ensures rigidity to the rigid pavement. The 2 to 3 % camber for rigid and flexible pavement respectively ensures efficient drainage during monsoon. The longitudinal drains on both the sides of the composite road are provided with gratings. Good subsurface drainage by providing Granular Sub Base (GSB) drainage layer and leading to longitudinal drains as shown Fig.1,The following items were executed while laying the composite road.

i) Earth work for extended portion, ii)Scarifying the existing B.T surface (5700mm width), iii) Compaction of original ground; iv) Wet Mix Macadam (WMM-below D.L.C and profile correction), v) Dry Lean Concrete (D.L.C -100mm); vi) Polyethylene 125-micron separation sheet; vii) Pavement Quality Concrete (PQC -240mm); viii) Granular Subbase (G.S.B-150mm), ix) Primer coat; x) Tack coat; xi) Bituminous macadam (B.M-50mm); xii) Semi dense bituminous macadam (SDBC-25mm); xiii) RCC Longitudinal drains; xiv) RCC median; xv) RCC Krebs; xvi) RCC NP3; xvii) Hume pipes for cross ducts; xviii) CC Pavers for footpaths.

3.2.4 Assessment of the condition of the road by visual inspection and Non-Destructive Tests (NDTs) after thirteen years of its execution.

Total bitumen surface area of the road = 1.121km = 1121m

Width of asphalt lane on both sides = 1.800m, Area of asphalt surface (2*1121*1.8) = 4035.60m^2

Worn-out wearing coat = Out of 1121m length nearly about 900m in up direction (From Jubilee Circle to K.C.D Road) for an average width of 90mm the wearing coat is worn-out. In down direction only a small portion of 100m length with 600m wide is worn-out.

Area of worn-out wearing coat = (1* 900* 0.9 + 1*100*0.6) =870.00m^2

Area of worn-out wearing coat = 21.55 %

The visual inspection parameters are depicted in Table 7.

Table 7: Performance of road as observed by visual inspection

Item	Observations	Remarks
i) Surface deformation	Corrugations	**Nil**
	Rutting	**Nil**
	Shoving	**Nil**
	Shallow depressions	**Nil**
	Settlement and Upheaval	**Nil**
ii) Cracking	Fatigue Cracking	**Nil**
	Transverse Cracking	Very few
	Longitudinal Cracking	**Nil**
	Edge Cracking	**Nil**
	Reflective Cracking	**Nil**
iii) Disintegration	Potholes	**1**
	Patches	**Nil**
iv) Surface defects	Ravelling	**Nil**
	Bleeding	**Nil**
	Wearing of surface coat (WC)	**21.55%**

The wearing of finishing coat is predominantly seen in up direction. The reason for this is the improper camber and chocking of gratings provided in longitudinal drains walls for surface drainage. Sample photos showing worn-out wearing coat are depicted in Fig 3, 3.1 and 3.2.

Fig. 3. At Ch.0+200 Dn.

Fig. 3.1 At Ch 0+400 Dn.

Fig. 3.2 At Ch 0+400 Up

The present qulality of PQC is tested all along the stretch by Rebound Hammer test (RHT) and Ultrasonic Pulse Velocity Test (UPVT). KSI model rebound hammer and Proceq Pundit Lab, Swiss made models are used for RHT and UPVT respectively. The testing is shown in sample photos Fig 4 & 5.

Fig. 4 USPVT

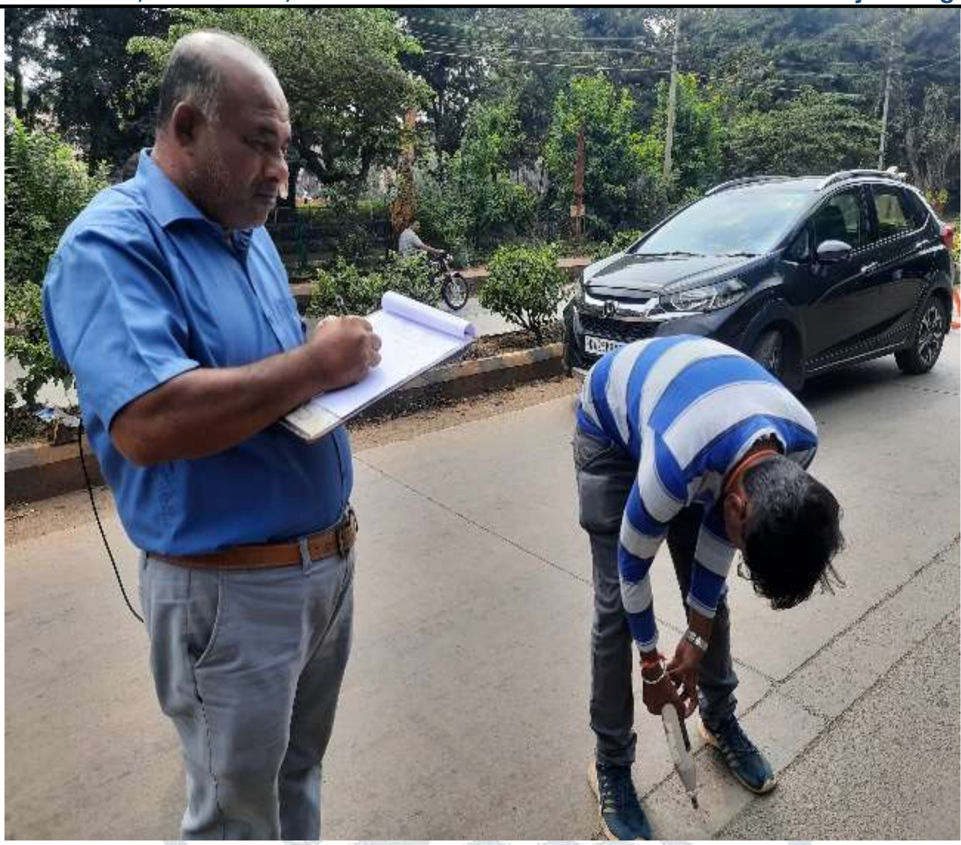

Fig. 5 RHT

Sample Photos of RHT and UPVT test readings are shwon in Fig 6 and 7.

Fig. 6 RHT reading

Fig 7 UPVT reading

The entire stretch of composite road has single pothole and deterioration except about 22% wearing of wearing coat and hardly very few transverse cracks at the junction of RCC cross beams and asphalt portion shown in Fig.8. These cracks are developed due to non-adhesion between two different materials and insufficient compaction at the junction.

Fig. 8 Transverse cracks at the junction of R.C.C beam and Asphalt stretch.

There are no depressions, lateral deformations, allegation cracks, ruts formation on the entire stretch even though there is a significant increase in traffic since 2009. At the same time, no maintenance expenditure is incurred on this road since its construction except removal brass and shrubs at the edges of the asphalt lanes. Sample photo of the present condition in Fig. 9.

Fig. 9. View at Jubilee Circle Dharwad

Rebound Hammer Test and Ultrasonic Pulse Velocity test results are shown in Tables 8 and 9.
Description of test structure: RCC beams and PQC in the stretch under stud
Environmental condition:

- Temperature 30oC and
- Humidity 51%.

Table 8. Test results of Rebound Hammer Test

Sl. No	Location	Chainage	Member	Rebound numbers						Mode of test	Rebound Index	Compressive strength in MPa
				RH1	RH2	RH3	RH4	RH5	RH6			
1	Towards Jubilee Circle at	0+000	PQC	40	38	36	37	39	39	V-Down	38	42.18
2			Beam	39	42	39	42	40	40	V-Down	40	45.13
3		0+200	PQC	38	42	41	38	39	36	V-Down	39	44.15
4			Beam	36	35	35	40	43	38	V-Down	38	42.18
5		0+400	PQC	39	38	41	38	38	39	V-Down	39	44.15
6			Beam	37	37	38	45	35	34	V-Down	38	42.18
7		0+600	PQC	36	39	38	40	45	38	V-Down	39	44.15
8			Beam	34	39	48	40	41	37	V-Down	40	45.13
9		0+800	PQC	37	37	45	45	38	34	V-Down	39	44.15

10			Beam	45	45	35	36	38	37	V-Down	39	44.15
11	Towards K..C. D	0+800	PQC	38	37	39	42	45	36	V-Down	40	45.13
12			Beam	38	37	39	38	36	34	V-Down	37	41.20
13		0+600	PQC	37	34	35	38	38	39	V-Down	37	41.20
14			Beam	37	38	39	36	40	38	V-Down	38	42.18
15		0+400	PQC	40	41	44	37	36	36	V-Down	39	44.15
16			Beam	39	38	38	34	34	36	V-Down	37	41.20
17		0+200	PQC	40	45	42	38	38	37	V-Down	40	45.13
18			Beam	40	36	38	38	34	34	V-Down	37	41.20
19		0+000	PQC	35	36	37	37	36	39	V-Down	37	41.20
20			Beam	42	43	39	35	35	35	V-Down	38	42.18

Table 9. Ultrasonic Pulse Velocity Test results.

Sl. No	Location	Chainage	Member	Distance Between probe in mm	Method of test	Time T1 in micro sec.	Time T2 in micro sec.	Velocity in km/sec	Correction factor in km/sec	Velocity after adding correction factor	Quality of concrete
1	Towards Jubilee Circle at	0+000	PQC	100	Indirect	21.40	46.70	3.953	0.50	4.45	Good
2			Beam	100	Indirect	18.90	43.90	4.000	0.50	4.50	Excellent
3		0+200	PQC	100	Indirect	21.90	48.60	3.745	0.50	4.25	Good
4			Beam	100	Indirect	20.90	45.70	4.032	0.50	4.53	Excellent
5		0+400	PQC	100	Indirect	22.90	45.40	4.444	0.50	4.94	Excellent
6			Beam	100	Indirect	20.40	44.90	4.082	0.50	4.58	Excellent
7		0+600	PQC	100	Indirect	21.40	47.40	3.846	0.50	4.35	Good
8			Beam	100	Indirect	19.40	42.90	4.255	0.50	4.76	Excellent
9		0+800	PQC	100	Indirect	20.90	47.40	3.774	0.50	4.27	Good
10			Beam	100	Indirect	14.40	37.60	4.310	0.50	4.81	Excellent
11	Towards K..C. D	0+800	PQC	100	Indirect	21.90	46.60	4.049	0.50	4.55	Excellent
12			Beam	100	Indirect	21.40	44.20	4.386	0.50	4.89	Excellent
13		0+600	PQC	100	Indirect	21.40	49.10	3.610	0.50	4.11	Good
14			Beam	100	Indirect	19.40	41.70	4.484	0.50	4.98	Excellent
15		0+400	PQC	100	Indirect	20.90	46.10	3.968	0.50	4.47	Good
16			Beam	100	Indirect	20.40	41.20	4.808	0.50	5.31	Excellent
17		0+200	PQC	100	Indirect	20.40	48.10	3.610	0.50	4.11	Good
18			Beam	100	Indirect	18.90	42.10	4.310	0.50	4.81	Excellent
19		0+000	PQC	100	Indirect	21.40	50.60	3.425	0.50	3.92	Good
20			Beam	100	Indirect	21.40	46.40	4.000	0.50	4.50	Excellent

IV Conclusions:

From the instant study the following conclusions can be drawn**.**

- The RHT test results showed that the compressive strength is more than 40MPa i.e. More than the designed strength.
- The UPV test results showed the quality of rigid pavement ranges from good to excellent.
- The major reason for the well-functioning of the road without any distress for thirteen years after its execution is due to the confinement of all the edges of both flexible and rigid pavements. In addition, the proper design, method of execution, use of quality materials, provision of proper, sufficient surface and subsurface drainage system with proper supervision during execution have resulted in a good, sustainable, and durable composite pavement structure.
- This type of composite pavement with the parameters considered in the design and execution may suitably be adopted for any other roads.

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