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ROUNDABOUTS: STANDARDS, DESIGN AND RESEARCH IN ITALY

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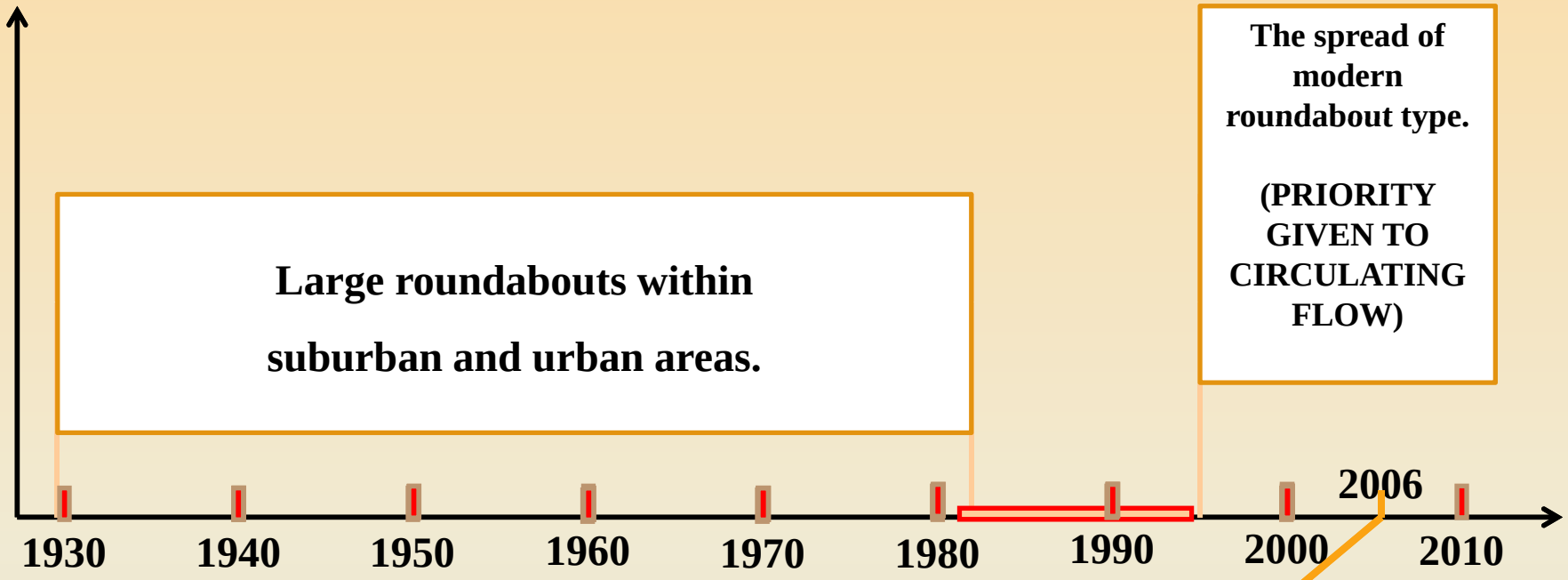
International Roundabout Design and Capacity Seminar

in connection with the TRB 6th International Symposium on Highway Capacity and Quality of Service

- Stockholm , 1st July-

ITALIAN EVOLUTION OF ROUNDABOUT BUILDING



Geometric and functional Italian standard to construct roads intersections (with chapter on roundabout design) **[D.M.19/06/2006]**

In Italy the spread of modern roundabouts occurred more than a decade later than in other European countries

1930 ÷ beginning of 1980s: LARGE ROUNDABOUTS

•SUBURBAN AREAS

intersections between roads with high traffic volume

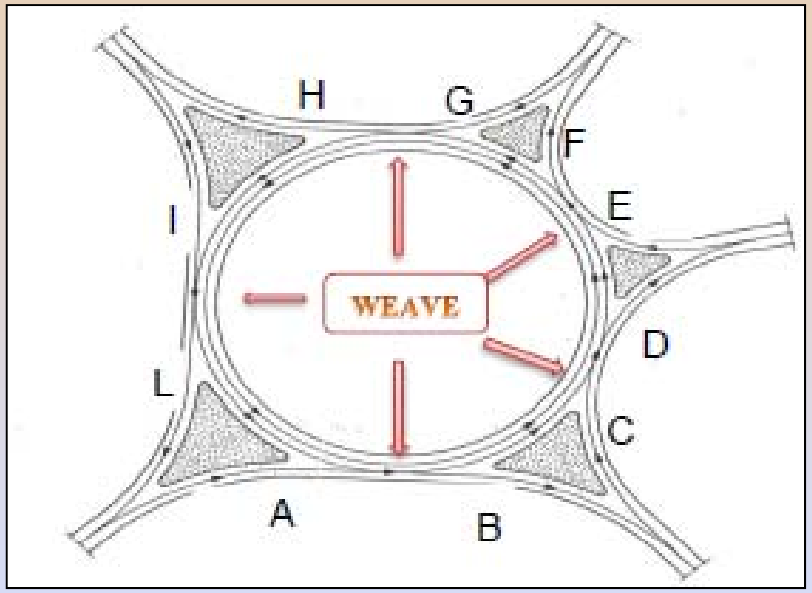
•URBAN AREAS

Reorganisation of historic squares and new great squares

LARGE ROUNDABOUT **AFFI - VERONA**

LARGE ROUNDABOUT ***RE SQUARE*** - **ROME**

Circulatory roadway as a set of weave zones (AB, CD, EF, GH, IL)



- large land use
- poor legibility of the intersection
- High crash rates

between 1980s and 1990s

BREAK IN THE

ROUNDABOUTS BUILDING

SPREAD OF TRAFFIC SIGNS IN URBAN AND SUBURBAN AREAS

SIGNALIZATION OF LARGE ROUNDABOUTS

STANGA SQUARE
PADUA

IN ITALY FROM MID 1990s

MODERN ROUNDABOUTS HAVE BEEN BUILT

RIGHT OF WAY FOR THE CIRCULATING TRAFFIC

SMALL LAND USE

SIZE CONSISTENT WITH THOSE ADOPTED IN OTHER EUROPEAN COUNTRIES

SMALL ROUNDABOUT
COMO

COMPACT ROUNDABOUT
BRESCIA

IN ITALY FROM MID 1990s

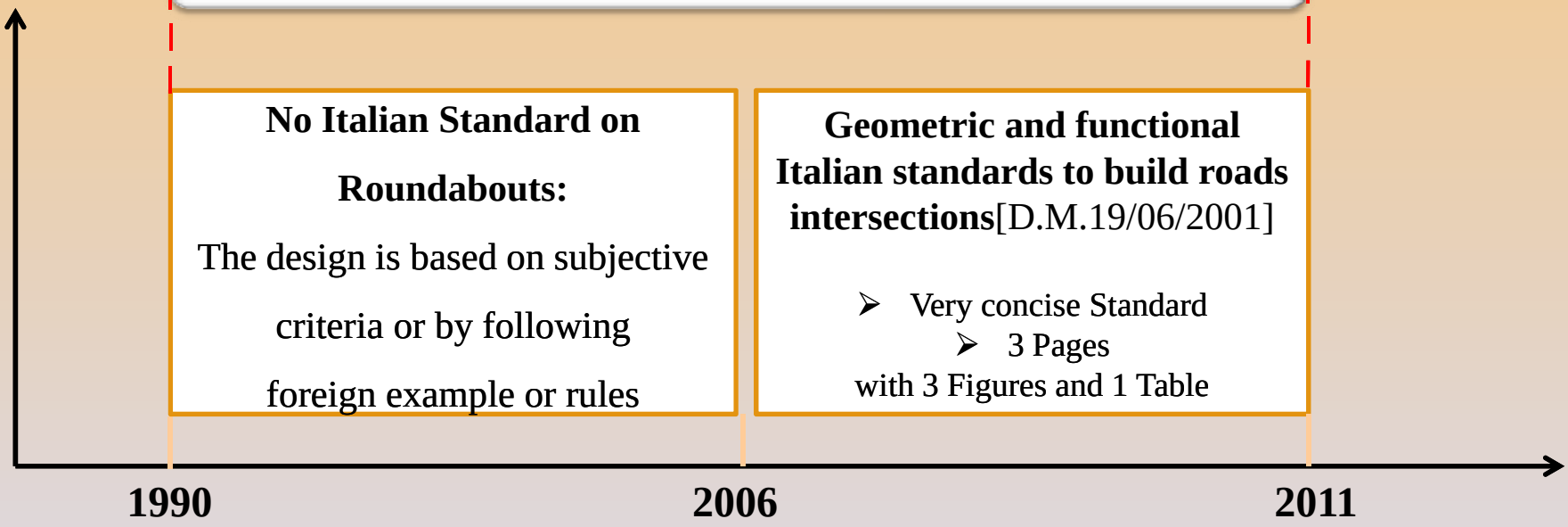
OLD LARGE ROUNDABOUTS HAVE BEEN MODERNIZED

RIGHT OF WAY FOR THE CIRCULATING TRAFFIC

“LUCIANO ROMAGNOLI” ROUNDABOUT - BOLOGNA

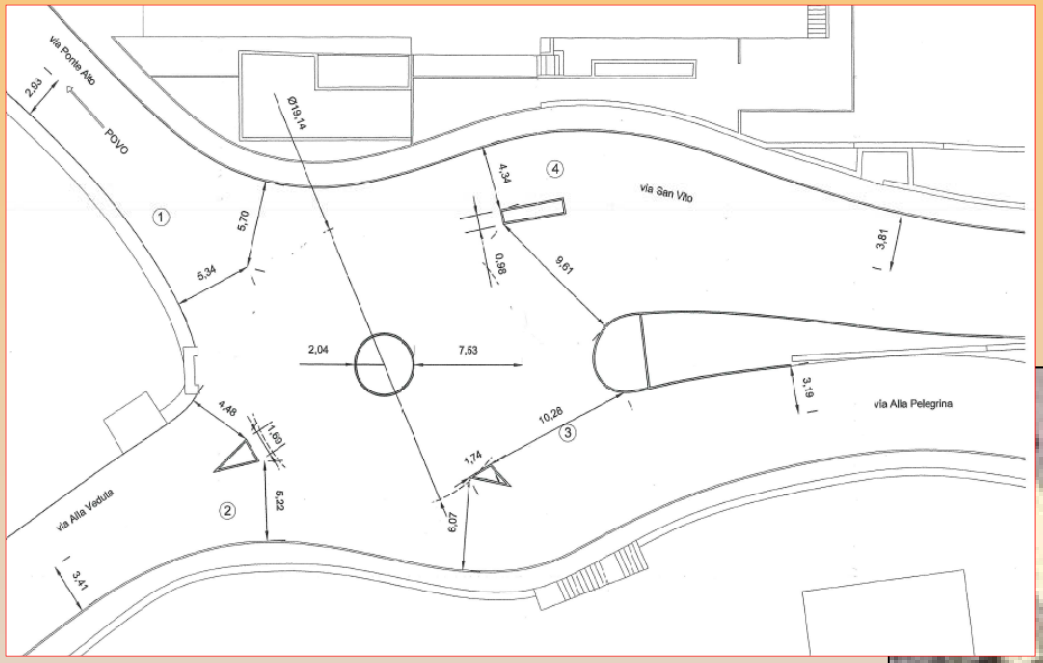
SITUATION FROM 1990s TO NOWADAYS

SOME THOUSAND OF ROUNDABOUTS HAVE BEEN BUILT IN ITALY



In Italy, till now, when the roundabouts are placed within the existing roads network, both for urban and suburban areas, totally atypical solution can be observed

These solutions are characterized by some odd and varied configurations



ATYPICAL ARRANGEMENT IN TRENTO

The only relation with the roundabout type is the circulatory organization of the flow in the intersection

INTRODUCTION TO THE ITALIAN ROADS FUNCTIONAL TYPES ACCORDING TO DM. 5.11.2001

A
Freeway
(rural and urban)

B
Expressway

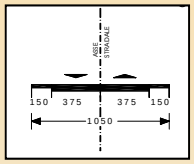
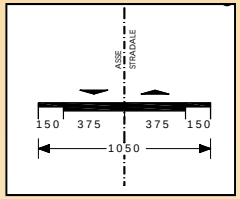
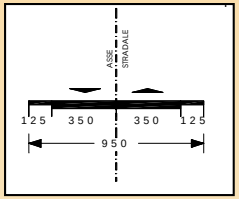
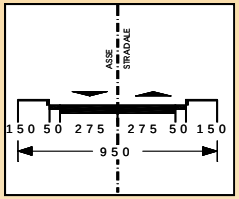
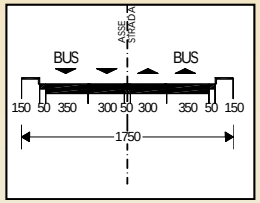
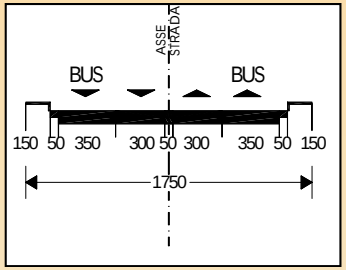
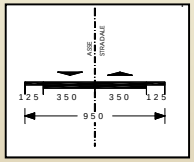
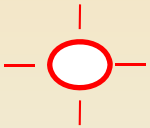
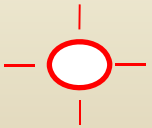
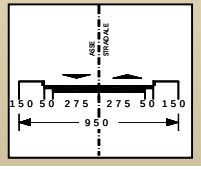
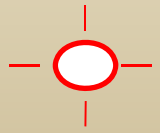
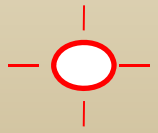
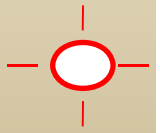
C
Two-lane rural roads

D
Arterial highway
(urban)

E
Major streets

F
Local streets
Local roads

ROADS WHERE A ROUNDABOUT CAN BE INTRODUCED ACCORDING TO THE ITALIAN STANDARD

	C Two-lane rural roads	E Major streets	F_{rural} Local roads	F_{urb} Local Street
C **Two-lane rural roads**				
E **Major streets**				
F_{rural} **Local roads**				
F_{urb} **Local Street**				

SPANISH EXAMPLE

IN ITALY
THIS CASE OF ROUNDABOUT BETWEEN EXPRESSWAY AND TWO-LANE RURAL ROADS CANNOT BE BUILT

ITALIAN ROUNDABOUT STANDARD

The Roundabout Standard is contained in the Italian Standard on the intersections

Italian geometric and functional Standard to build road intersections
[D.M.19/06/2006]

The rules are concise: The Italian Standard involves only 3 pages including 3 figures and 1 table

4.4 Intersezioni lineari a raso

4.5 Intersezioni a rotatoria

4.5.1 Tipologie

Si considerano tre tipologie fondamentali di rotatorie in base al diametro della circonferenza esterna (limite della corona rotatoria, in riferimento alla Figura 10):
- rotatorie convenzionali con diametro esterno compreso tra 40 e 50 m;
- rotatorie compatte con diametro esterno compreso tra 25 e 40 m;
- mini rotatorie con diametro esterno compreso tra 14 e 25 m.

Per sistemazioni con "circolazione rotatoria", che non rientrano nelle tipologie su esposte, il dimensionamento e la composizione geometrica debbono essere definiti con il principio dei tronchi di scambio tra due bracci contigui. In questi casi le immissioni devono essere organizzate con appositi dispositivi.

Un ulteriore elemento distintivo tra le tre tipologie fondamentali di attrezzatura rotatoria è rappresentato dalla sistemazione dell'isola circolare centrale, che può essere resa in parte transitabile per le manovre dei veicoli pesanti, nel caso di mini-rotatorie con diametro esterno compreso fra 25 e 18 m, mentre lo diventa completamente per quelle con diametro compreso fra 18 e 14 m; le rotatorie compatte sono invece caratterizzate da bordure non sormontabili dell'isola centrale.

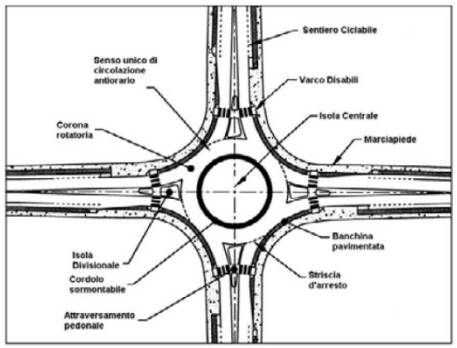


Figura 10

In base alla classificazione delle intersezioni riportata nel capitolo 3, in ambito extraurbano l'adozione di mini rotatorie viene limitata agli incroci tipo F/F tra strade locali, mentre le rotatorie compatte sono consentite per gli incroci tipo C/C, C/F, F/C.

Un'intersezione stradale risolta a rotatoria va accompagnata lungo i rami di approccio da idonea segnaletica, se necessario anche integrativa rispetto a quella di preavviso, e da eventuali ulteriori strumenti di regolazione della velocità.

4.5.2 Larghezza delle corsie

Con riferimento alla Figura 10, si definiscono le larghezze degli elementi modulari delle rotatorie, secondo quanto indicato nella Tabella 6.

Elemento modulare	Diametro esterno della rotatoria (m)	Larghezza corsie (m)
Corsie nella corona rotatoria (*), per ingressi ad una corsia	≥ 40	6,00
	Compreso tra 25 e 40	7,00
	Compreso tra 14 e 25	7,00 - 8,00
Corsie nella corona rotatoria (*), per ingressi a più corsie	≥ 40	9,00
	< 40	8,50 - 9,00
Bracci di ingresso (**)		3,50 per una corsia 6,00 per due corsie
Bracci di uscita (*)	< 25	4,00
	≥ 25	4,50

(*) deve essere organizzata sempre su una sola corsia.
(**) organizzati al massimo con due corsie.

Tabella 6

4.5.3 Geometria delle rotatorie

Il criterio principale per definire la geometria delle rotatorie riguarda il controllo della deviazione delle traiettorie in attraversamento del nodo. Infatti, per impedire l'attraversamento di un'intersezione a rotatoria ad una velocità non adeguata, è necessario che i veicoli siano deviati per mezzo dell'isola centrale.

La valutazione del valore della deviazione viene effettuata per mezzo dell'angolo di deviazione β (vedi Figura 11) Per determinare la tangente al ciglio dell'isola centrale corrispondente all'angolo di deviazione β, bisogna aggiungere al raggio di entrata $R_{e,2}$ un incremento b pari a 3,50 m. Per ciascun braccio di immissione si raccomanda un valore dell'angolo di deviazione β di almeno 45°.

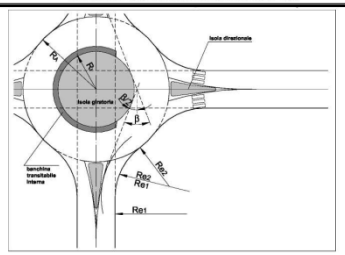


Figura 11 - Elementi di progetto e tipizzazione delle rotatorie

Negli incroci a rotatoria, i conducenti che si approssimano alla rotatoria devono vedere i veicoli che percorrono l'anello centrale al fine di cedere ad essi la precedenza o eventualmente arrestarsi; sarà sufficiente una visione completamente libera sulla sinistra per un quarto dello sviluppo dell'intero anello, secondo la costruzione geometrica riportata in Figura 12, posizionando l'osservatore a 15 metri dalla linea che delimita il bordo esterno dell'anello giratorio.

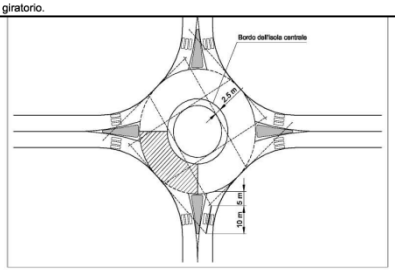
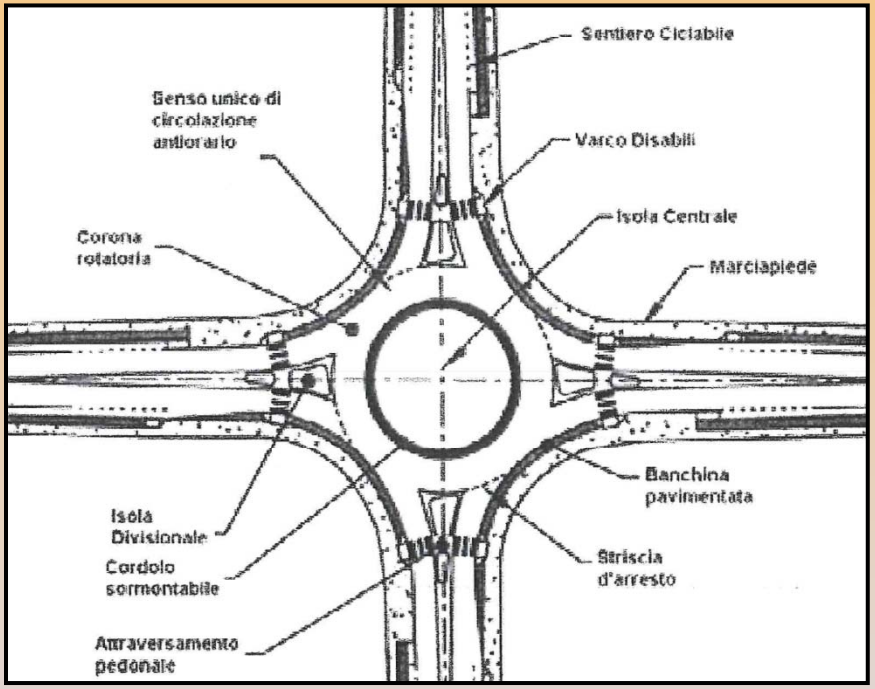
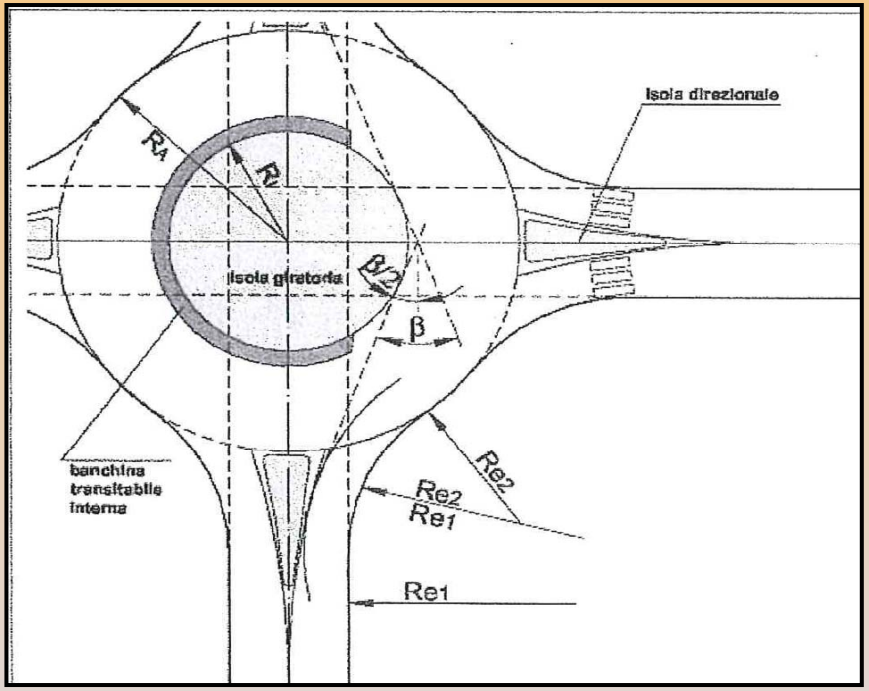


Figura 12: Campi di visibilità in incrocio a rotatoria

PROTOTYPE-LIKE DESIGN AND GEOMETRIC FEATURES OF ROUNDABOUTS BY ITALIAN STANDARD

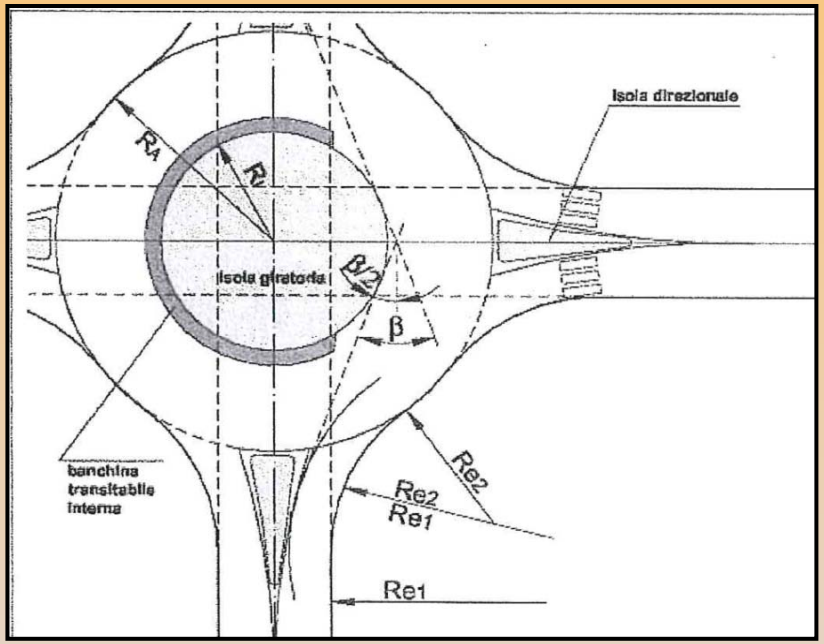


PROTOTYPE -LIKE DESIGN



GEOMETRIC FEATURES

DEFINITION OF ROUNDABOUT TYPES BY USING THEIR INSCRIBED CIRCLE DIAMETER ACCORDING TO THE ITALIAN STANDARD



	$D_{ext} = 2\ R_A$ [m]
MINI-ROUNDABOUTS	14 ÷ 25
COMPACT ROUNDABOUTS	25 ÷ 40
CONVENTIONAL ROUNDABOUTS	40 ÷ 50
"ROTARY CIRCULATION" LAYOUT (large roundabout)	-

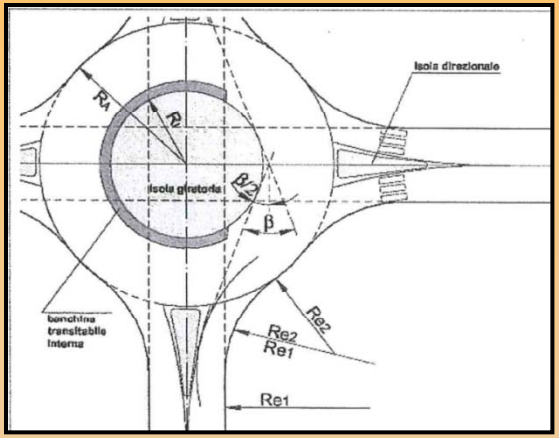
ITALIAN STANDARD VERSUS GERMAN STANDARD

	Italian nomenclature	German nomenclature	
	D_{ext} (m)	D_{ext} (m)	
Mini-roundabouts	14 - 25	13 - 24	
Compact roundabouts	25 - 40	26 - 60	urban: 26 – 35 (single-lane circle) rural: 30 - 45 (single-lane circle)
			Urban and rural: 40 - 60 (double-lane circle)
Roundabouts	40 - 50	55 - 80	
"Rotary circulation" layout	-	-	

ITALIAN STANDARD VERSUS SWISS STANDARD

	Italian nomenclature	Swiss nomenclature
	D_{ext} (m)	D_{ext} (m)
Mini-roundabouts	14 - 25	14 - 20 (town centers, residential areas, urban areas)
Small roundabouts	-	18 - 24 (town centers, residential urban, and suburban areas)
Compact roundabouts	25 - 40	22 - 35 (urban, suburban, and rural areas)
Roundabouts	40 - 50	-
Big roundabouts (Swiss Standard nomenclature)	-	> 32-40 (rural areas)
"Rotary circulation" layout (Italian Standard nomenclature)	-	-

GEOMETRIC FEATURES ACCORDING TO ITALIAN STANDARD



NO INSTRUCTIONS ON Ra1, Ra2, Rc2, Re1

NO INSTRUCTIONS ON THE INSIDE PAVED APRON WIDTH

NO INSTRUCTIONS ON THE LOCATION OF CROSSWALKS AND CYCLE PATHS ON THE ROUNDABOUTS

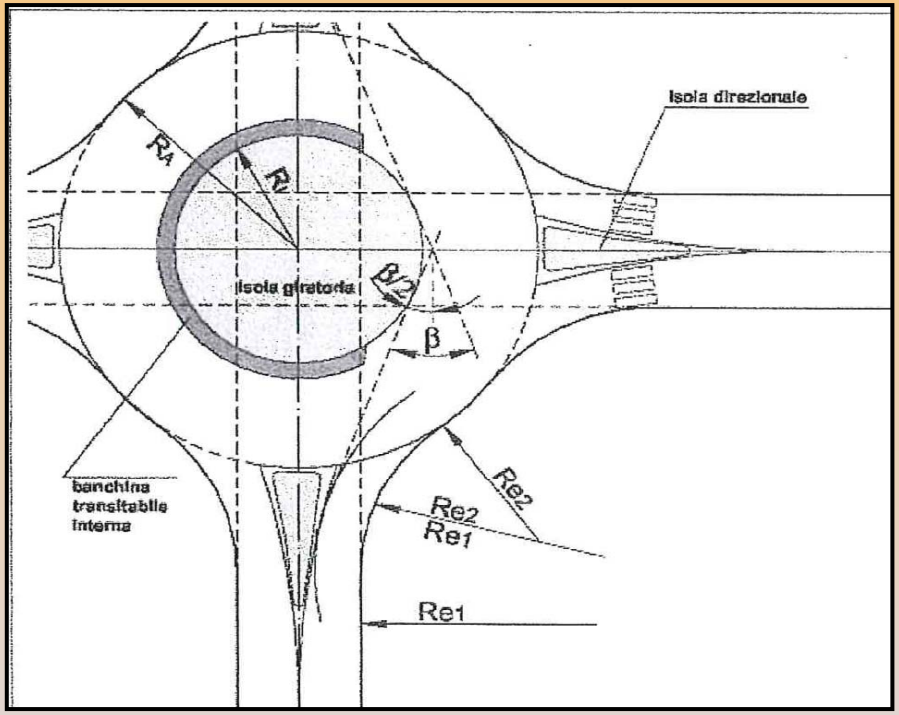
NO INSTRUCTIONS ON GEOMETRIC FEATURES OF THE SPLITTER ISLANDS

NO INSTRUCTIONS ON VERTICAL GRADES AND CROSS-SLOPES FOR THE CIRCULATING ROADWAY AND LEGS

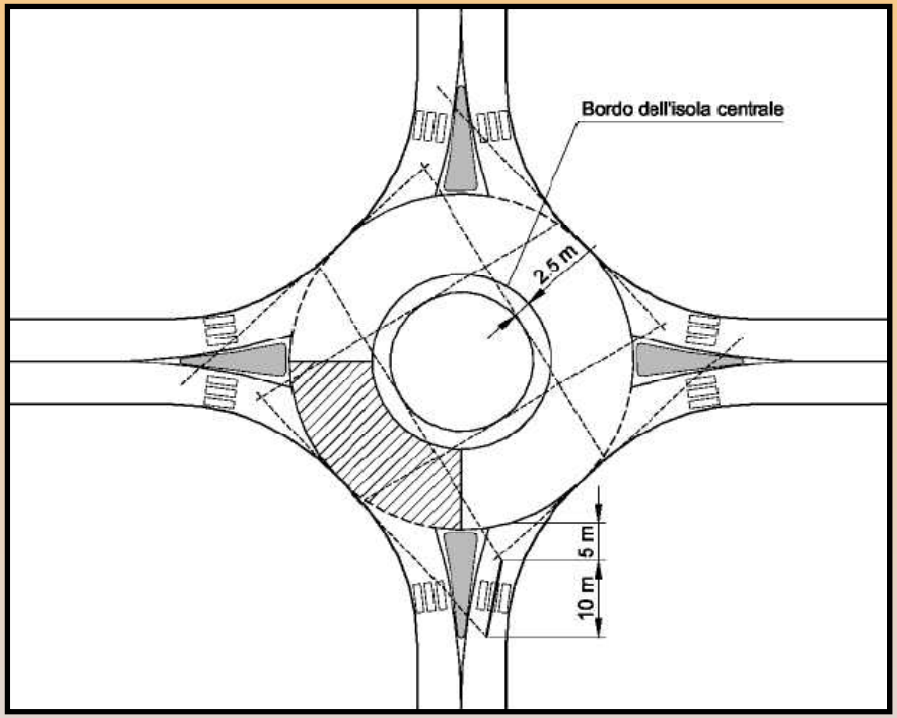
	Mini Roundabouts	Compact Roundabouts	Convectional Roundabouts
Inscribed Circle diameter (D_{ex})	14 ÷ 25 m	25 ÷ 40 m	40 ÷ 50 m
Maximum number of entry lanes	2	2	2
Maximum number of exit lanes	1	1	1
Entry legs width with a single entry lane	3,50 m	3,50 m	3,50 m
Entry lgs width with two entry lanes	6,00 m	6,00 m	6,00 m
Exit legs width	4,00 m	4,50 m	4,50 m
Circulatory Roadway	without lane marking	without lane marking	without lane marking
Circular roadway width with a single entry lane	7,00 ÷ 8,00 m	7,00m	6,00 m
Circular roadway width with two entry lanes	8,50 ÷ 9,00 m	8,50 ÷ 9,00 m	9,00 m
Circular Central Island	Partly practicable with external diameter between 18m ÷ 25m. Totally practicable with external diameter between 14m ÷ 18m	No practicable	No practicable

VERIFY ACCORDING TO ITALIAN STANDARD

ONLY CONCISE CHECKS ABOUT GEOMETRIC LAYOUT AND REQUIRED VISIBILITY AT ROUNDABOUT

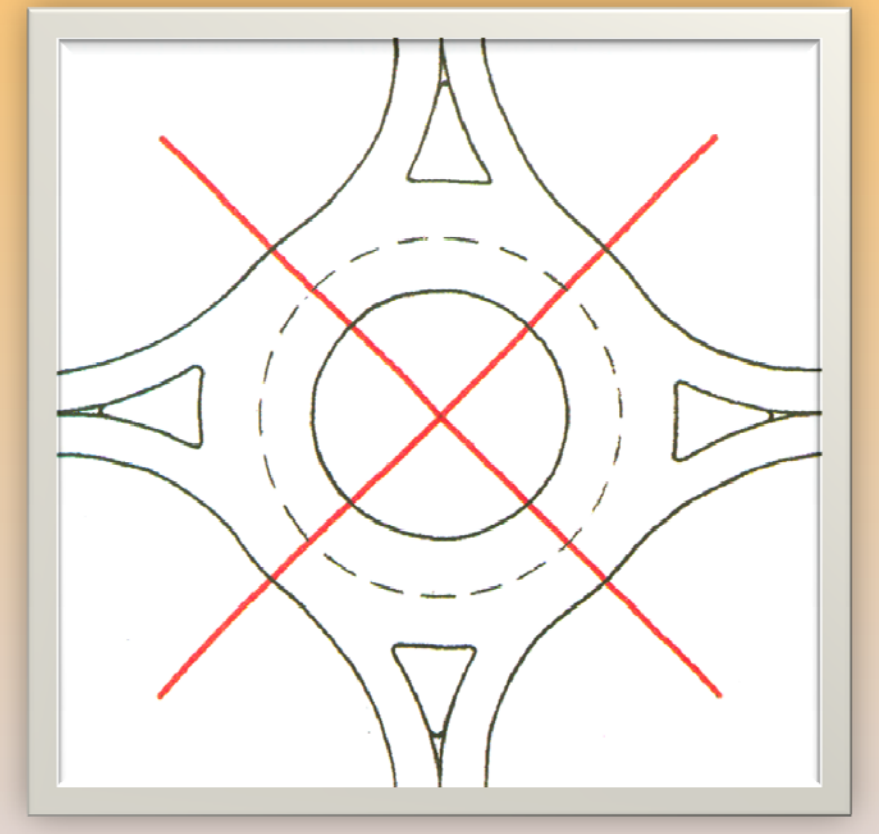


There must be a deviation angle $\beta > 45^{o}$



Dashed area must be clear of obstructions (with respect to each leg)

SPECIAL REQUIREMENTS OF THE ITALIAN STANDARDS

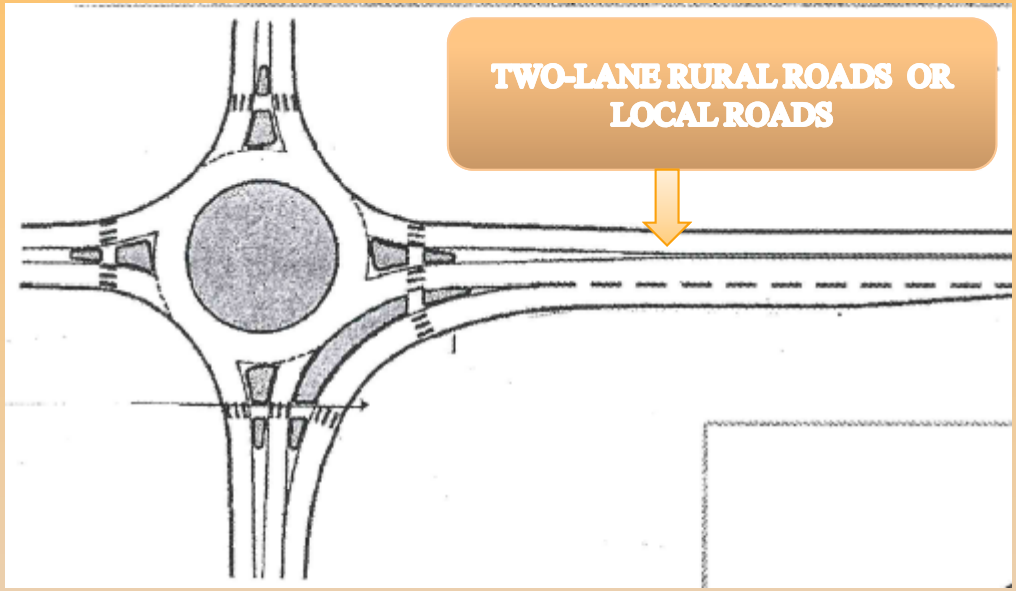


EXIT LANES FOR ALL ROUNDABOUTS ARE SINGLE LANE

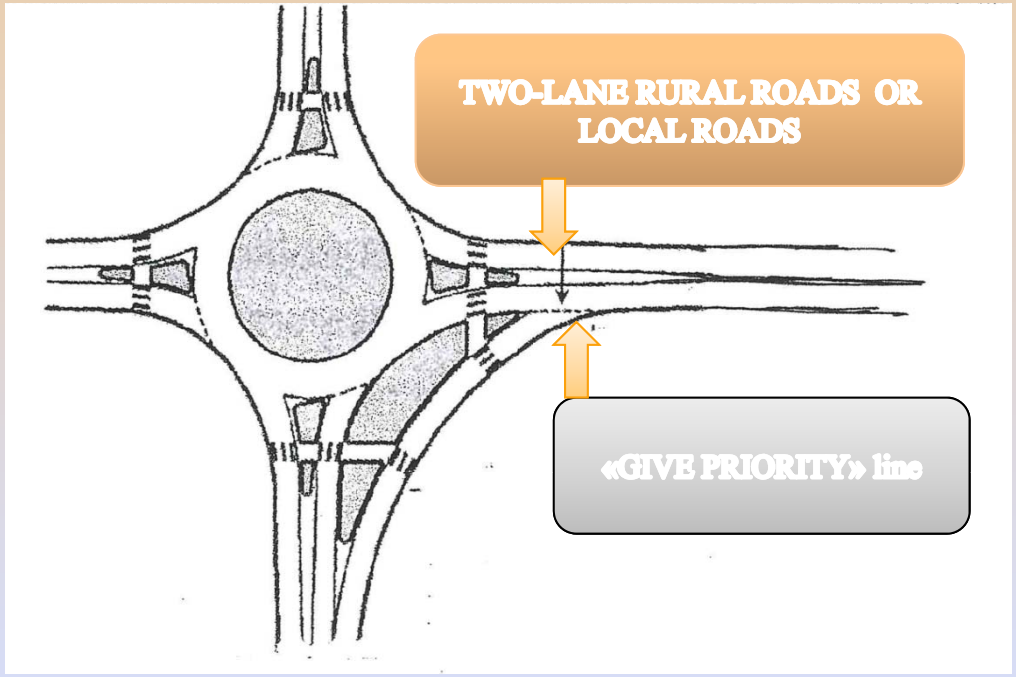
ENTRY LANES FOR ALL ROUNDABOUTS CAN BE DOUBLE LANE

NO MARKING LANES ON THE CIRCULATORY ROADWAY FOR ALL ROUNDABOUTS TYPES

SPECIAL REQUIREMENTS ACCORDING TO THE ITALIAN STANDARD



According to the Italian Standard for this type of roads, the approach lane is not accepted for right turn by-pass



THIS CONFIGURATION IS ACCEPTED BY ITALIAN STANDARD

BUT

This requirement does not reflect the literature and International Guidelines

SPECIAL REQUIREMENTS OF THE ITALIAN STANDARDS ABOUT CROSSWALKS

❖*Italian Roads Code* (2010)
❖*Rules for implementation of Italian Roads Code*

THE ONLY REQUIREMENT AT GRADE INTERSECTIONS IS

"…the crosswalk, if it exists, should be drawn before the stop line, leaving a space of at least 5 meters; in this case the pedestrians must be channeled into the intersection area via suitable protection systems"

THE ITALIAN STANDARD ON ROUNDABOUTS DOES NOT GIVE ISTRUCTIONS TO DEFINE THE EFFECT OF THE PRESENCE OF CROSSWALKS ON THE CAPACITY OF THE ENTRY AND EXIT LEGS

Reduced capacity at entry legs for urban roundabouts can be calculated using existing foreign procedures:

- *Marlow and Maycock*
- *Brilon, Stuwe and Drews*
- *CETE*

HYPOTHESIS: PRIORITY IS GIVEN TO THE PEDESTRIAN ON THE CROSSWALKS

Capacity at exit legs can be calculated by the same procedures as at the entry legs but great caution is required because there is still no specific validation

SPECIAL REQUIREMENTS OF THE ITALIAN STANDARDS ABOUT BICYCLE PATHS

❖ *Italian Roads Code* (2010)
❖ *Rules for implementation of Roads Italian Code*

THE ONLY REQUIREMENT AT GRADE INTERSECTIONS IS

"…the bicycle paths must be made available only to ensure continuity in the intersection areas"

❖ D.M. 30/10/1999, n.557
("Standard to define the technical features of the bicycle paths")

THE ONLY REQUIREMENT AT GRADE INTERSECTIONS IS

"…in the intersection areas where vehicles and pedestrians coexist, the bicycle path on the reserved lane must generally be placed side by side to the inside crosswalks edge, as well as to create a roundabout organization of cycling flow at the intersection with one-way counterclockwise"

SOME REMARKS ON ITALIAN ROUNDABOUTS STANDARD

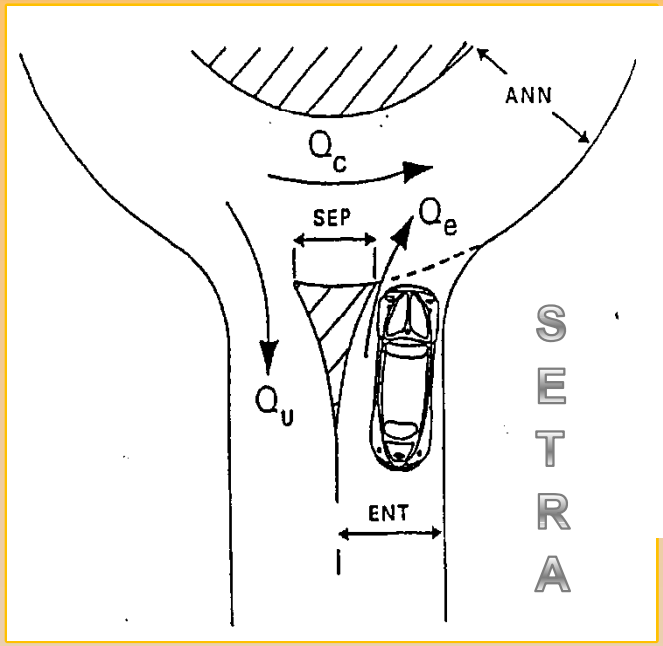
THE STANDARD IS VERY ESSENTIAL....AND

- NO INSTRUCTIONS ON SIZE AND LAYOUT OF ROUNDABOUTS according to the location (Urban, suburban, rural)
- NO PROVIDED INFORMATION ON THE geometric features of splitter islands, inside paved apron dimension, geometric features of entry and exit legs
- NO INSTRUCTIONS ON VERTICAL GRADES AND CROSS-SLOPES for the circulatory roadway and legs
- NO INFORMATION ABOUT LOCATION OF crosswalks and bicycle paths
- NO Italian capacity formula and NO instructions for using existing capacity formulas
- An assessment of the level of service is required but the criteria to be used are not specified

FRENCH FORMULA (S.E.T.R.A. AND CETUR)

In Italy doesn't exist a National Capacity Formula

the French formula of SETRA or CETUR is widely used



$$Q'_u = \frac{Q_u \cdot (15 - SEP)}{15} \qquad SEP < 15$$

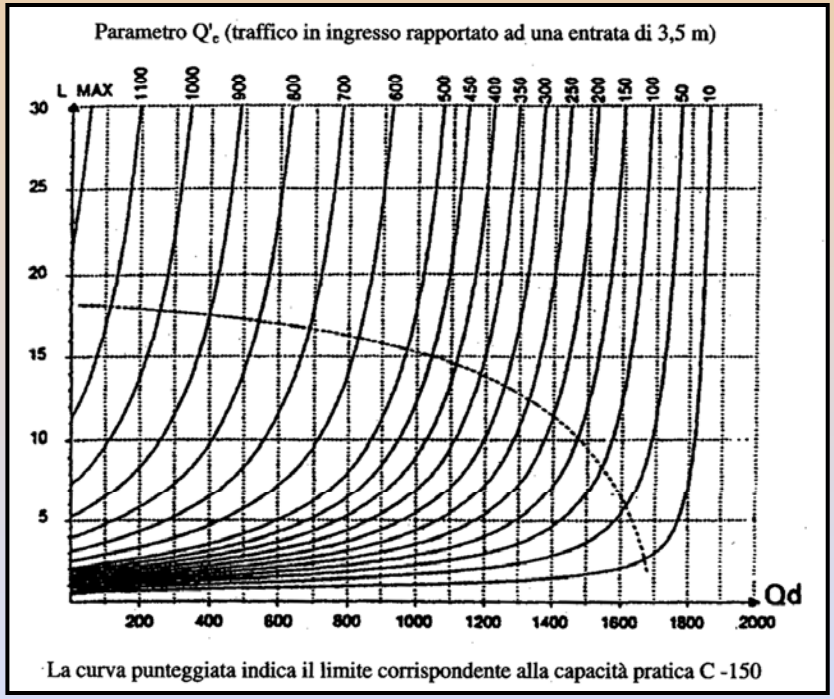
$$Q'_u = 0 \qquad SEP \geq 15$$

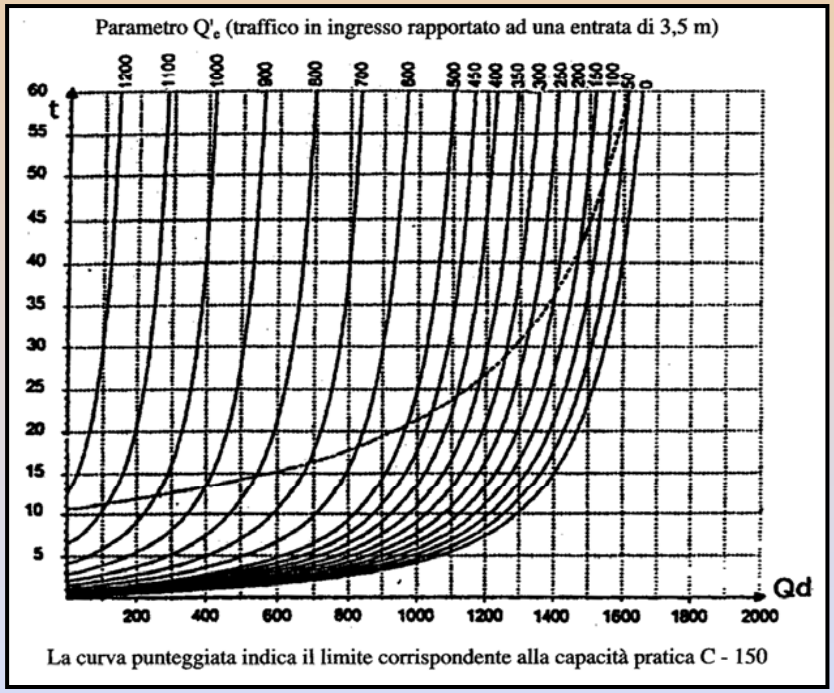
$$Q_d = \left(Q_c + \frac{2}{3} Q'_u \right) \left[1 - 0{,}085 (ANN - 8) \right]$$

$$C = (1330 - 0{,}7 Q_d) \left[1 + 0{,}1 (ENT - 3{,}5) \right]$$

$$C_p = C - 150 \qquad C_p = 0{,}8 \cdot C$$

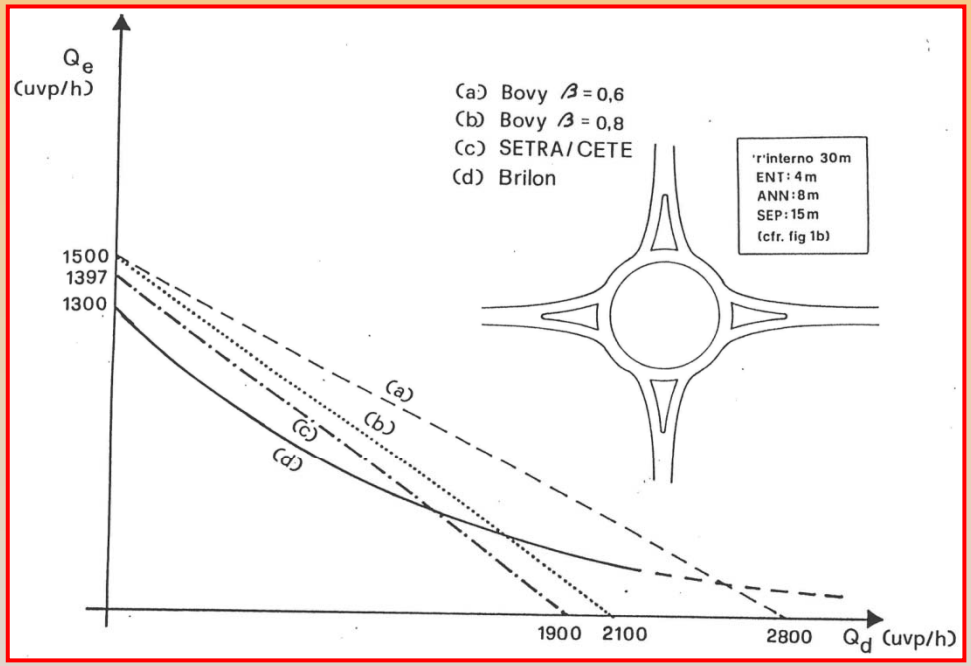
$$Q_e = \gamma (1500 - 0.83 \cdot Q_d)$$ ⇦ CETUR



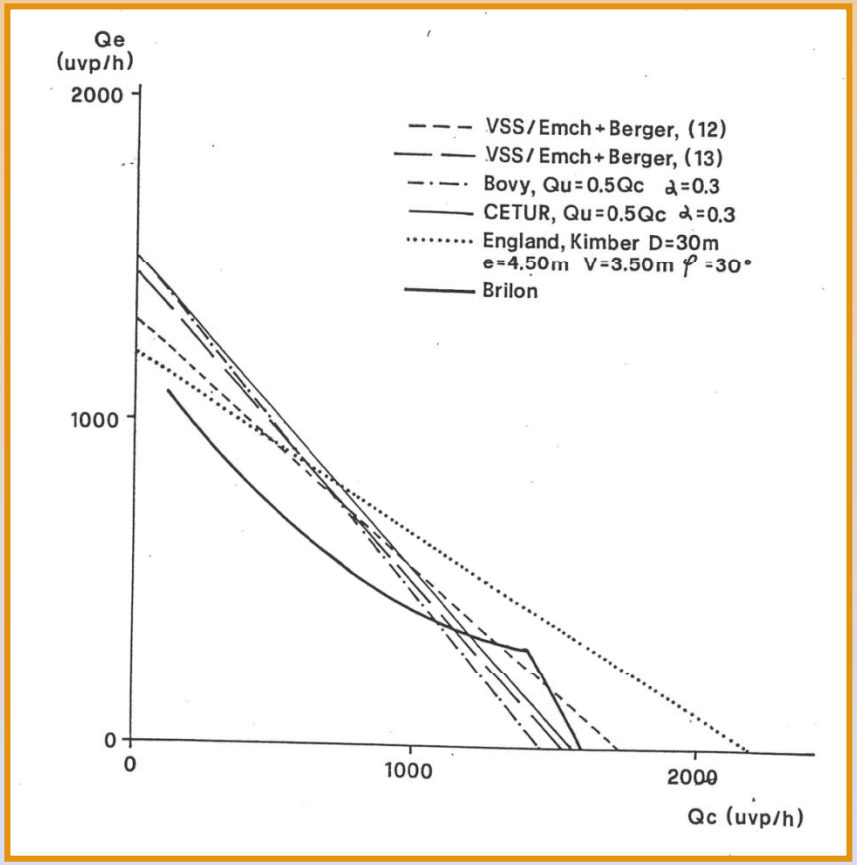


FRENCH CAPACITY FORMULAS VS OTHER CAPACITY FORMULAS

SETRA CAPACITY FORMULA VERSUS OTHER CAPACITY FORMULAS FOR A TYPE OF RURAL ROUNDABOUTS



CETUR CAPACITY FORMULA VERSUS OTHER CAPACITY FORMULAS FOR A MINI ROUNDABOUT WITH SINGLE ENTRY LANE



ITALIAN PRACTICE TO DESIGN THE ROUNDABOUTS

- **Until 2006** (when the **Standard** was issued) the design was performed by "subjective" criteria, or, at best, following International Guidelines or examples without the estimation of the capacity and levels of service

(ONLY GEOMETRIC DESIGN WITHOUT FUNCTIONAL CHECKS)

- After the publication of the Standard [**D.M. 19/04/2006**]

still

- in the intersection design, the Italian Standard is often not applied
- estimation of capacity, queue lengths and waiting times is not often performed to assess the level of service

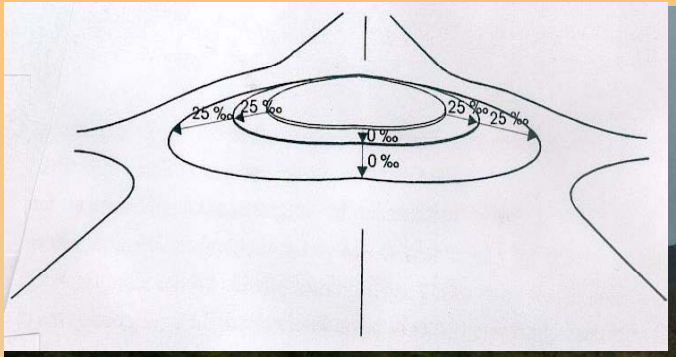
● Several design errors can be found in the geometric design of some roundabouts in Italy

RECENTLY WE ARE WITNESSING

A REVERSAL OF THIS TREND

VERTICAL ALIGNMENT ERROR: ROUNDABOUT ON STEEP SLOPES

ERRORS IN CENTRAL ISLAND AND PAVED APRON VERTICAL GRADES



ERROR: TOO TANGENTIAL ENTRY LEG

ERROR: TOO TANGENTIAL ENTRY LEG

TO BE AVOIDED

ODD CONFIGURATIONS

ERROR: CLOSENESS OF ENTRY AND EXIT LANE

ERROR IN THE LOCATION OF CROSSWALKS

RESEARCH ACTIVITIES ON ITALIAN ROUNDABOUTS

- **Until now** in Italy, unlike in other Countries, large and National co-ordinated analyses on existing roundabouts have not been carried out to assess the functional features and to develop one National Capacity Formula

- **Even today** experimental research addressing safety analysis for these types of intersections is not performed in Italy.

- Several studies on this topic are being performed by some University research groups

RESEARCH ACTIVITIES ON ITALIAN ROUNDABOUTS

The first studies in Italy were developed from 1995 to 1998 at the "Federico II" **University of Naples** (Esposito and Mauro)

The published documents achieved large national distribution among road technicians.

The studies went on at the University of Trent from 1990 (Mauro *et al.*) with methodical theoretical research on operational performance and the safety of roundabouts and turbo-roundabouts, at International and National level; an Italian Version of the KREISEL software has been developed to evaluate the capacity index and waiting times

Some other Italian research groups working on the topic of roundabouts include:

University of Trieste (Camus *et al.*): functional analyses of roundabouts using systemic general procedures which are also really applicable

University of Palermo (O. Giuffrè *et al.*): functional and safety analyses on atypical configurations of roundabouts

University of Catania (Canale *et al.*): crash prediction models for roundabouts and assessment of level of service for mini-roundabout and all types of roundabout.

University of Torino (Bassani *et al.*): safety and consistency analysis for the roundabouts

RESEARCH ACTIVITIES ON ITALIAN ROUNDABOUTS

Italian research is mainly addressed

- to assess the reliability of the roundabouts scheme
- to perform crash prediction models for roundabouts
- to carry out performance analyses of roundabouts
- to compare roundabouts versus both intersections with traffic lights and turbo roundabouts, applying technical-economic and functional criteria

Some handbooks on geometric-functional design of the roundabouts have had a good spread in Italy:

- V. Curti *et al.*
  (Roundabouts. Design and Assessment to arrange intersections into roundabouts)
- M. Villa
  (Roundabout intersections: knowing the working to suggest the design)
- S. Canale *et al.*
  (To design the roundabouts: Procedures to design and verify the roundabouts intersections)
- O. Bodrito
  (Roundabouts: Analysis and design)

REMARKS AND CONCLUSIONS

Finally, thanks to the experience gained and the diffusion of know-how, there are all the conditions to reach a good practice in roundabouts – regarding both design and building in Italy

THANKS FOR YOUR ATTENTION